SUPPORT TO QUALITY

AND

RELIABILITY ASSURANCE LABORATORY

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FOREWORD

This report, an addendum to LMSC-A842316, presents the results of work performed in support of MSFC's Quality and Reliability Assurance Laboratory. The task was divided into three parts as follows:

- Task 38A – Detailed Acceptance and Inspection Test Plan for ATM
- Task 38B – Seismic Pad Requirements
- Task 38C – Pointing Control System Test and Checkout Guidelines

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Task 38A

DETAILED ACCEPTANCE AND INSPECTION TEST PLAN FOR ATM

Task 38A was a direct assistance effort to R-QUAL-AE. In support of the task, an engineer from LMSC's Huntsville Research and Engineering Center was assigned to the R-QUAL-AE Office. The ATM Acceptance and Inspection Test Plan will define the ATM acceptance and inspection requirements from the piece-part to the system level. During the task, a test plan outline and approximately 60 percent of a test plan were completed.

Task 38B

ATM SEISMIC PAD REQUIREMENTS – BUILDING 4708

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1.0 Introduction

1.1 General

The Apollo Telescope Mount (ATM) requires extreme accuracy in the alignment of the experiments with respect to the fine sun sensor (FSS) and to each other. Pointing stability is even more critical. Once a target is selected for examination in orbit, the Experiment Pointing System (EPS) on the experiment package must automatically hold the attitude within 2.5 arc-sec in pitch and yaw. Ground testing of the Pointing Control System (PCS) is complicated by gravity and by the interaction of a hinge between the experiment package and the Rack.

As a part of integrated system testing in Building 4708, the PCS will be subjected to an alignment verification test and a dynamic test of pointing stability. Since the base reference proposed for use in alignment verification is the local level, it is essential that the structural support during the test remain level within an order of magnitude greater than the tolerance specified for the ATM. Tests made of the stability of the present floor in the high bay of Building 4708, which is proposed for use during ATM system testing, show that due to natural and induced causes the floor is subject to movement and tilt with deviations comparable in magnitude to the accuracies specified for the ATM. Isolation of the ATM test setup from these floor disturbances appears necessary so that the alignment and dynamic response obtained will not be significantly degraded by facility movements.

1.2 Test Article Configuration

Integrated system testing of the ATM will be accomplished using the complete ATM in the launch configuration. The LM ascent stage will not be attached during the test. Preliminary information concerning ATM design may be found in Refs. 1 and 2. A summary of general characteristics is as follows:

- Diameter to SLA mounting points – approximately 20 ft
- Overall height including experiment package – approximately 12 ft
- Experiment package – 6 ft 10 in. diam. by 10 ft 10 in. long (gimballed at c.g. and supported on Rack)
- Weight – not to exceed 25,000 lb in the test configuration
- Mounting points (4) – 90 deg apart, at sta. 1818.069
- C. G. of ATM/LM – x direction, sta. 1812.4
- C. G. of ATM only – x direction, sta. 1775.0
- C. G. of experiment package – x direction, sta. ______
- Critical frequency of ATM in static test mode ______ Hz
- Critical frequency of ATM in dynamic test mode ______ Hz
- Critical frequency of ATM in experiment package in dynamic test mode ______ Hz

(See subsection 3.1 for a description of the test setup.)

1.3 Accuracy Requirements

Prelaunch alignment accuracy requirements are given in Ref. 3. Section 8 of Ref. 4 indicates the reference axes and static co-alignment requirements.

1.4 Environmental Control

The test stand and seismic pad will be in an enclosed area environmentally controlled to a class 10,000 cleanroom (Federal Standard 209a) during the test. The enclosure and environmental control system will be described in other documents. Vibrations created by the air conditioning equipment must be isolated or considered in the design of the seismic pad. Section 6 of Ref. 4 specifies the environmental conditions. The enclosures and environmental control system, which will probably be of the laminar flow type, have not yet been designed.

1.5 Present Floor Condition in Test Bay

The present floor in the test bay of Building 4708 is concrete, laid on grade in accordance with standard industrial construction practices. A number of cable trenches run through and around the area proposed for use. The floor has been cut and patched to such an extent that no sizable portion of it is considered monolithic.

In May of 1967 tests were made of variations in level of the floor at the proposed ATM test location during an 8-day period. The report of Mr. D. Johnston, R-ASTR-GCC, who conducted the test, is contained in Ref. 5. Pertinent data have been extracted and are contained in Table 1-1. It will be noted that the peak-to-peak tilt for the 8-day period is 5 arc-sec and the tilt due to equipment operation in the vicinity is on the order of 2 arc-sec. Vibration frequencies and their amplitudes were not determined.

Table 1-1

SUMMARY CHART FOR FLOOR STABILITY TESTS CONDUCTED IN BUILDINGS 4708 & 4755

	DAILY FLOOR MOVEMENT IN $\pm$ DIRECTION			
	Bldg. 4708	Bldg. 4755		
No. of days tested at ea. location	5/8 - 5/15/67 arc-second	Point "A" 5/19 - 5/26/67 arc-second	Point "B" 6/9 - 6/19/67 arc-second	Point "C" 6/19 - 6/27/67 arc-second
1	2.4	7.5	.1	.5
2	.9	6.0	≈0	2.0
3	1.0	.8	≈0	2.8
4	1.0	17.5	.1	1.5
5	.5	4.2	.4	2.5
6	.7	2.0	.4	.8
7	.8	3.5	.6	1.0
8	2.25	2.8	.5	2.0
9			.3	1.0
10			.4	
11			.3	
Peak-to-peak movement for total period of test	5.0	23.5	1.2	2.8
Movement due to personnel activity	.3 to .5	.5	.3	.3 to .4
Movement due to lift on tow trucks	2.0	4.0	1.0	2.0

The above figures are only valid for the particular time and location of the test conducted.

2.0 Seismic Pad Criteria

2.1 Size and Layout

The seismic pad, located in Building 4708 as shown in Fig. 2-1, must be sufficiently massive to provide the stability specified in subsection 2.2; however, as a minimum, ample space will be provided on the pad around the test stand to set up the test equipment and perform the required test activity. See Figs. 2-2 through 2-8 for a suggested layout. The dimensions shown are tentative. The depth in particular may change if transient loads are applied which have not yet been defined.

2.2 Stability Requirements

The level of the surface of the seismic pad shall not vary more than 1 arc-sec in 24-hr. This requirement does not apply during periods of identifiable earthquake activity, movement of a storm front through the area, or during a static firing of a large motor in the MSFC test area. ATM alignment verification will not be attempted during these events. Isolation from adjacent activity shall effectively dampen transmission of vibrations. Examples of major causes of vibration in the immediate area which must be controlled or dampened by design, include operation of the large bay doors, overhead cranes, fork lifts, and large trucks. The mass relationship of the pad to the test setup must be such that frequencies from 3.- to 15.0 Hz* will be effectively dampened to an amplitude on the instrument plate (see subsection 2.5.1) of less then 20 percent.

2.3 Isolation Methods

The seismic pad must not touch any adjacent facility or structure. The intervening space should contain air only. It would appear from the tilt readings

* Frequency to be revised if conditions require when critical frequency of the ATM and test setup have been established.

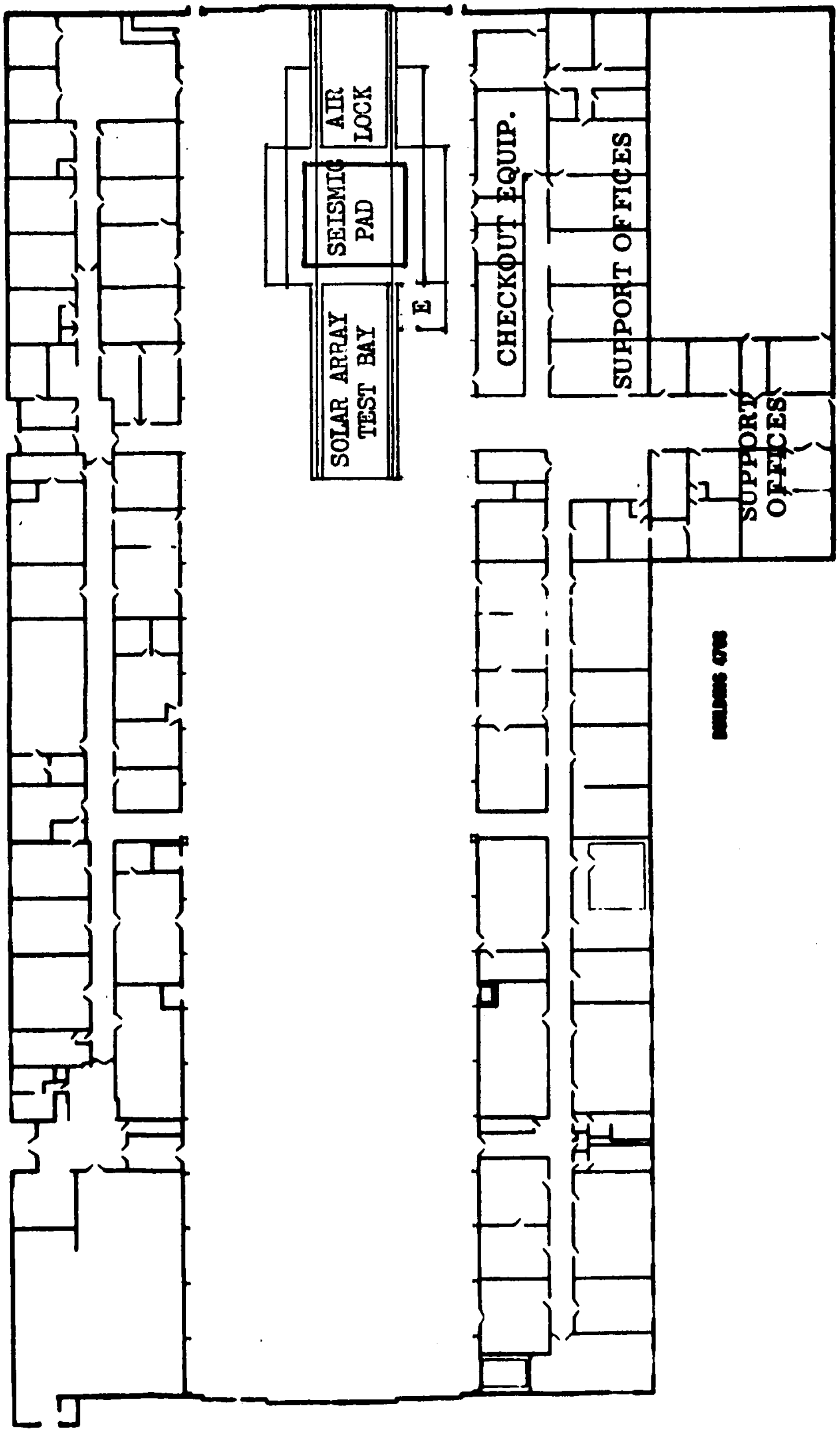


Fig. 2-1 Seismic Pad Proposed Location in Building 4708

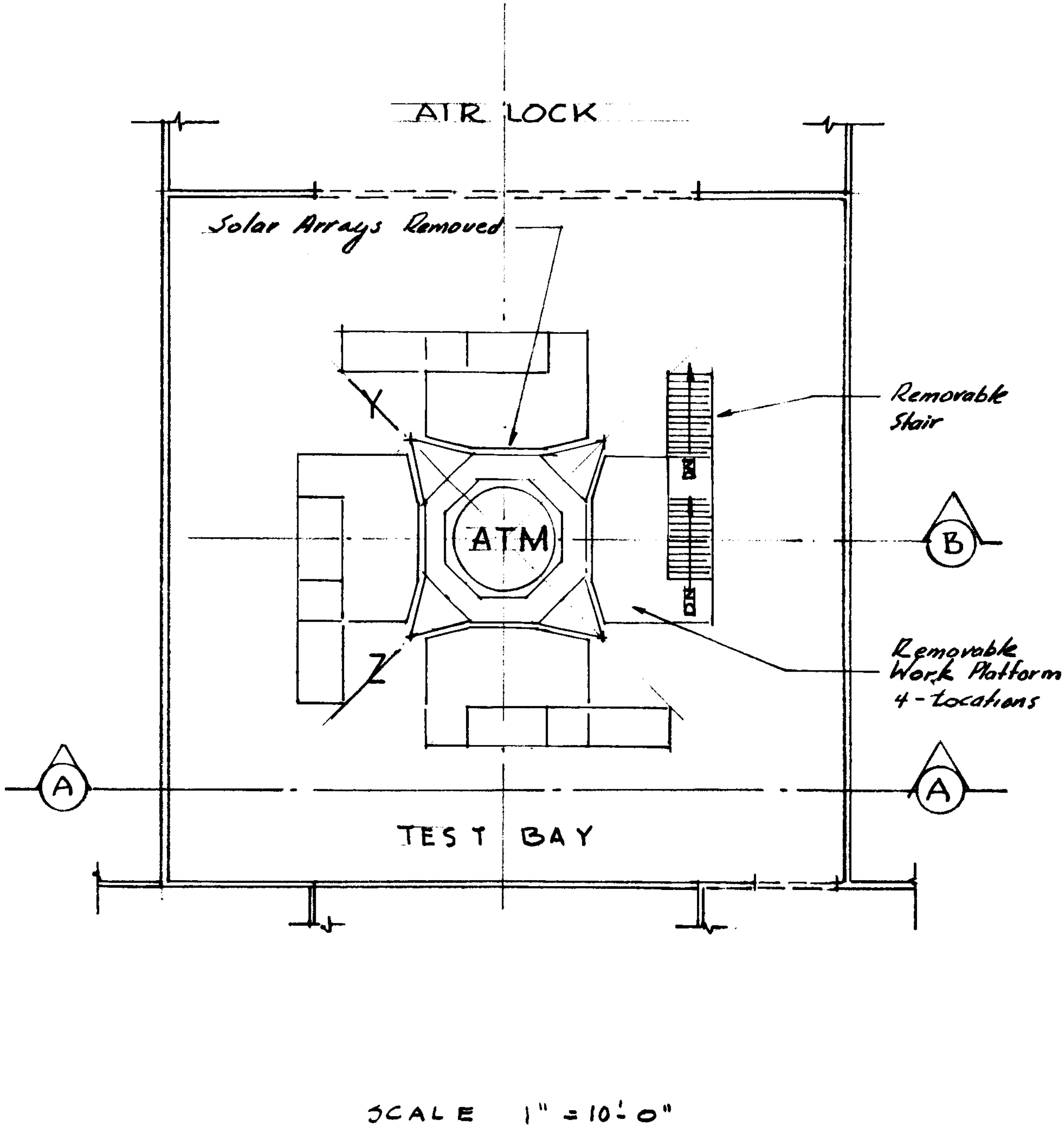


Fig. 2-2 Plan, Test Bay Enclosure

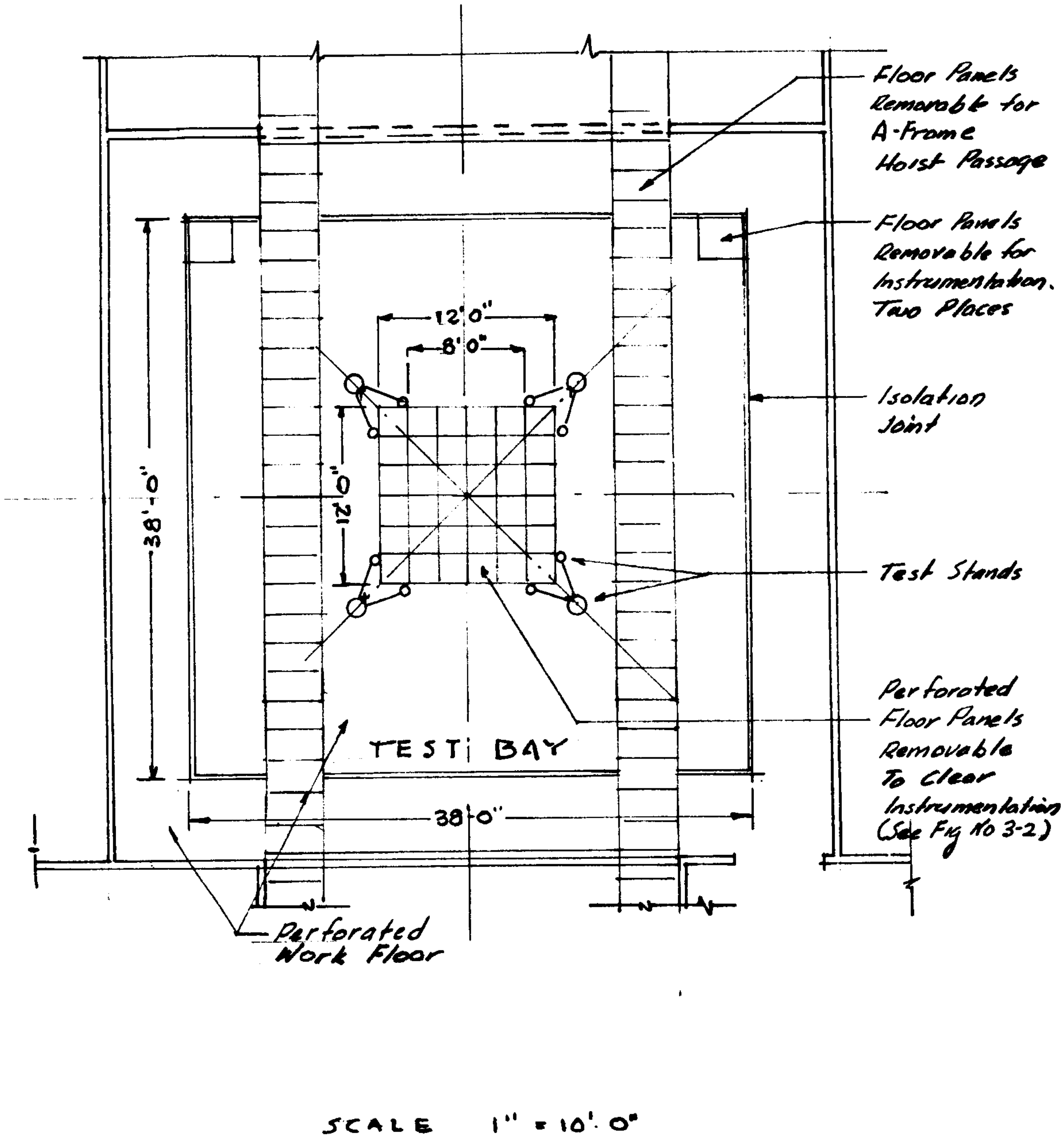


Fig. 2-3 Plan, Test Bay Enclosure Below ATM

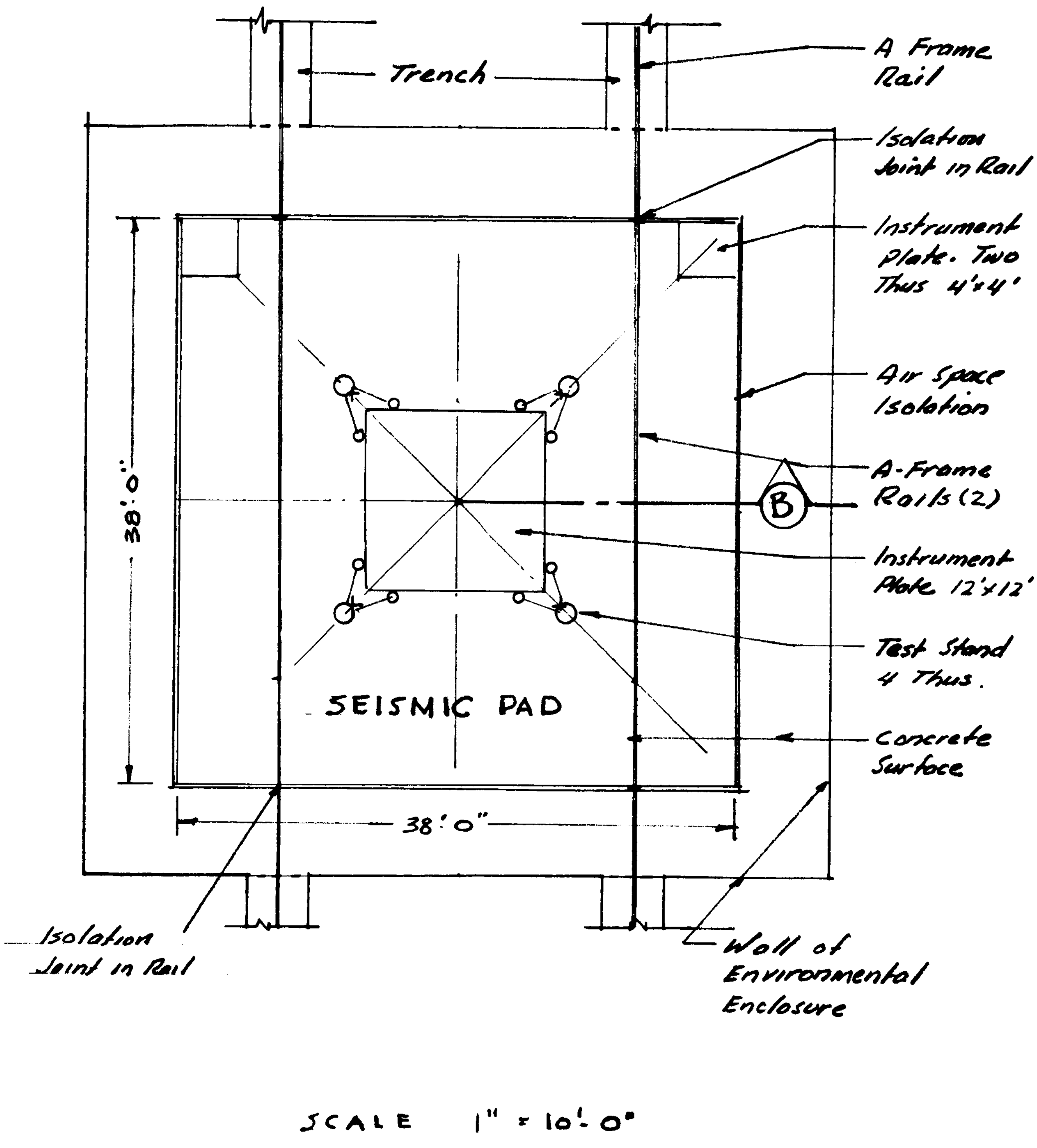


Fig. 2-4 Plan, Test Bay Enclosure Below Work Floor

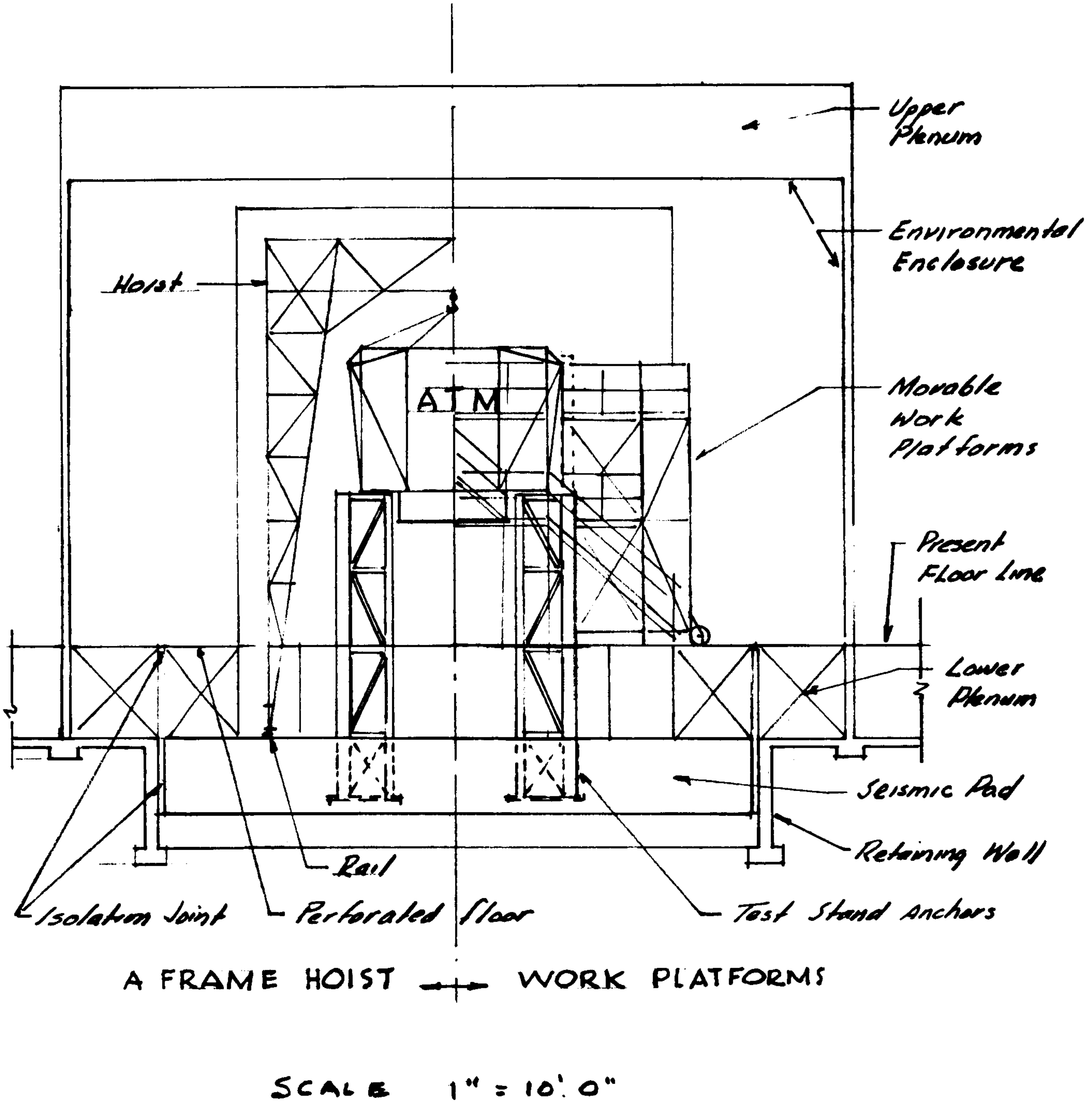


Fig. 2-5 Test Bay Enclosure, Section A-A

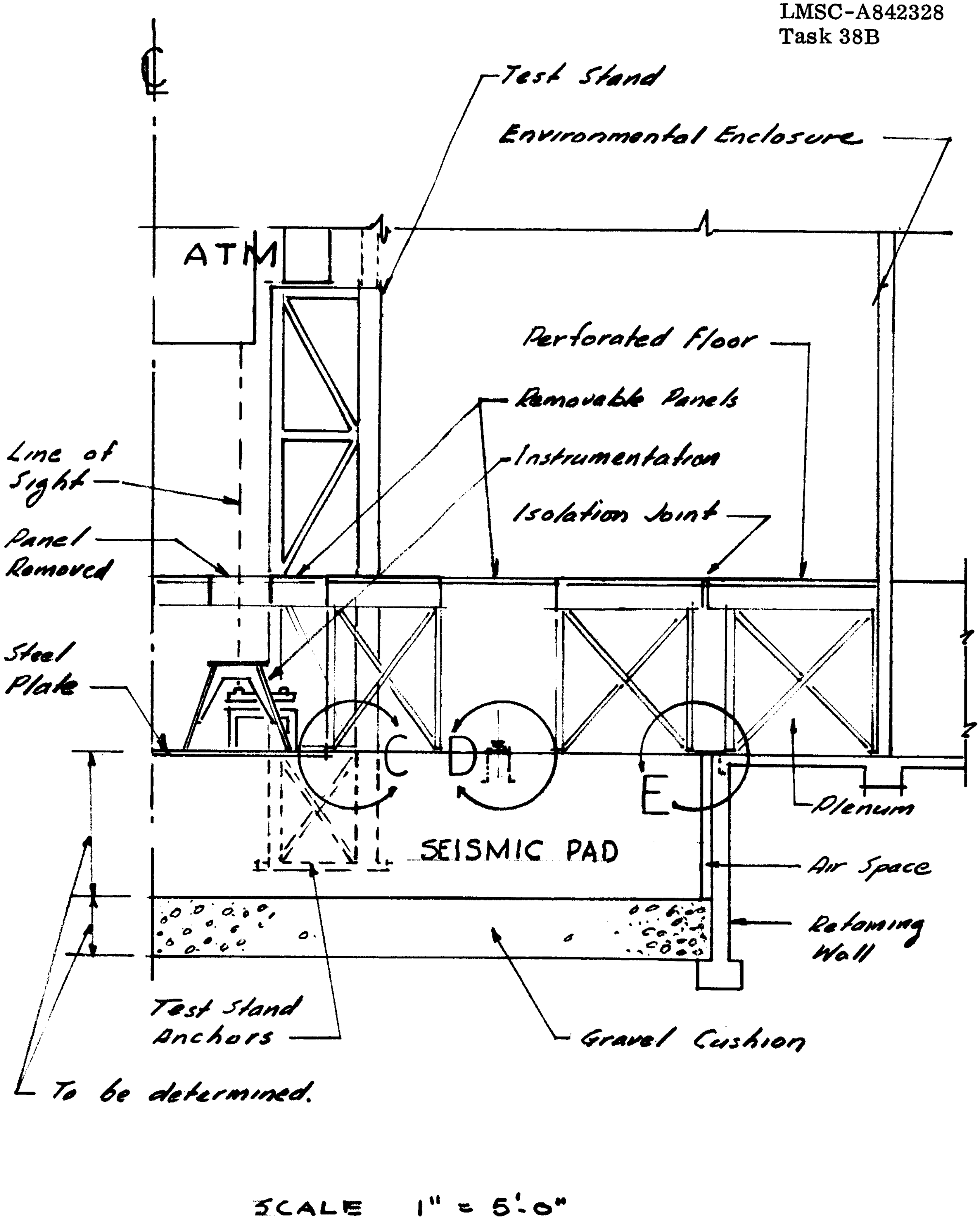


Fig. 2-6 Test Bay Enclosure, Section B

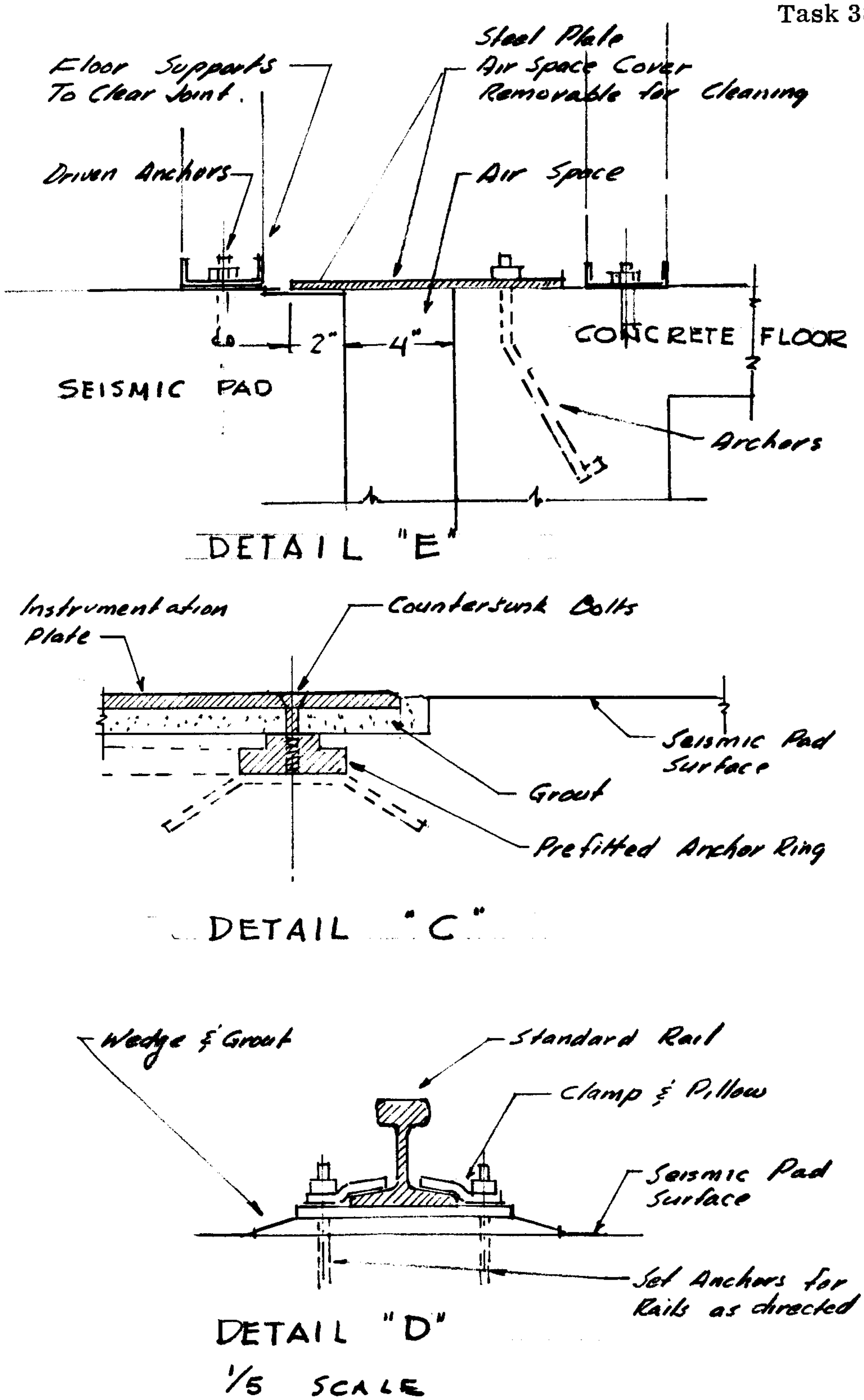


Fig. 2-7 Test Bay Enclosure, Details C, D, and E

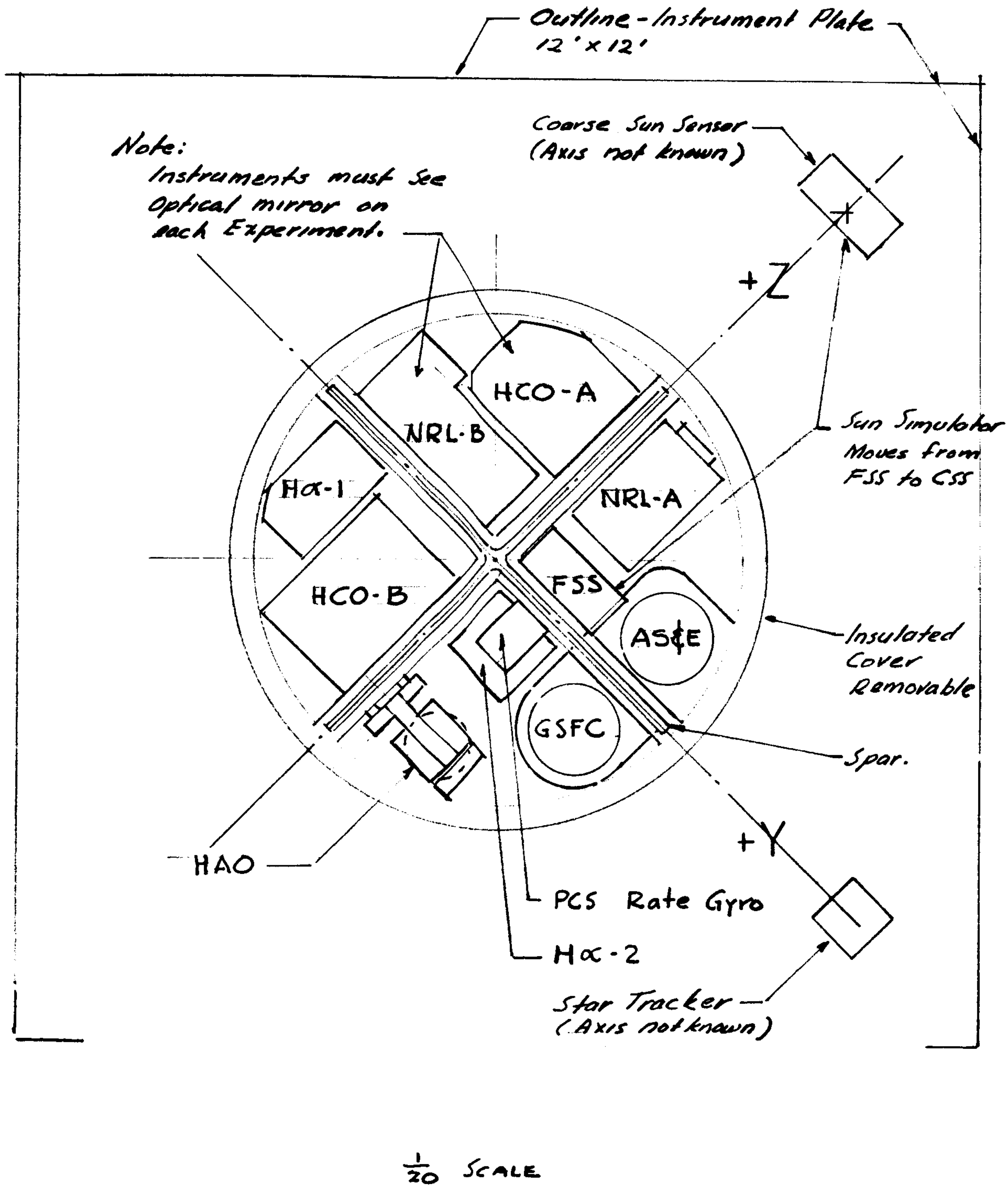


Fig. 2-8 Experiment Package, Typical Layout, Looking Down

Table 2-1

PRELAUNCH ALIGNMENT REQUIREMENTS

		RACK PHY REF AXES	SPAR PHY REF AXES	CMG	CSS	ST	HAO	NRLA	NRLB	HCO-A	HCO-B	GSFC	AS & E	HCO Hα	ATM WL	FSS	RATE GYROS
RACK PHY REF AXES	PITCH YAW ROLL		±0° 1' ±0° 1' ±0° 1'	±0° 30' ±0° 30' ±0° 30'	±0° 6' ±0° 6' ±1/2°	±0° 0' 30" ±0° 0' 30" ±0° 0' 30"											±1/2° ROLL ±1/2° GYRO —
SPAR PHY REF AXES	PITCH YAW ROLL	±0° 3' ±0° 3' ±0° 3'														±0° 2' ±0° 2' ±0° 2'	PITCH GYRO: — ±1/2° ±1/2° YAW GYRO: ±1/2° — ±1/2°
CMG	PITCH YAW ROLL	±1° ±1° ±1°															
CSS	PTCH YAW ROLL	±0° 12' ±0° 12' ±1°														±0° 10' ±0° 10' —	
ST	PITCH YAW ROLL	±0° 1' ±0° 1' ±0° 1'														±0° 2' 30" ±0° 2' 30" ±0° 1' 30"	
HAO	PITCH YAW ROLL															±0° 0' 10" ±0° 0' 10" ±0° 15'	
NRLA	PITCH YAW ROLL															±0° 0' 10" ±0° 0' 10" —	
NRLB	PITCH YAW ROLL										0° 0' 20" 0° 0' 20" 0° 4'					±0° 0' 10" ±0° 0' 10" ±0° 2'	
HCO-A	PITCH YAW ROLL										0° 0' 20" 0° 0' 20" 0° 30'			0° 0' 20" 0° 0' 20" —		±0° 0' 10" ±0° 0' 10" —	
HCO-B	PITCH YAW ROLL								±0° 1' ±0° 1' —	±0° 1' ±0° 1' ±1°				0° 0' 20" 0° 0' 20" —		±0° 0' 10" ±0° 0' 10" ±0° 2'	
GSFC	PITCH YAW ROLL															±0° 0' 10" ±0° 0' 10" —	
AS & E	PITCH YAW ROLL															±0° 0' 10" ±0° 0' 10" —	
HCO Hα (Hα 1)	PITCH YAW ROLL									±0° 1' ±0° 1' —	±0° 1' ±0° 1' —				0° 0' 20" 0° 0' 20" —	±0° 0' 10" ±0° 0' 10" —	
ATM WL (Hα 2)	PITCH YAW ROLL													±0° 1' ±0° 1' —		±0° 0' 10" ±0° 0' 10" —	
FSS	PITCH YAW ROLL		±0° 2' 30" ±0° 2' 30" ±0° 2' 30"		±0° 11' ±0° 11' —	±0° 4' 30" ±0° 4' 30" ±0° 4' 30"	±0° 1' ±0° 1' ±0° 30'	±0° 1' ±0° 1' —	±0° 1' ±0° 1' ±0° 4'	±0° 1' ±0° 1' —	±0° 1' ±0° 1' ±0° 4'	±0° 1' ±0° 1' —	±0° 2' ±0° 2' —	±0° 1' ±0° 1' —	±0° 1' ±0° 1' —		
SUN	PITCH YAW ROLL				±0° 3' ±0° 3' —		±0° 0' 20" ±0° 0' 20" ±1°	±0° 1' ±0° 1' ±5°	±0° 0' 2.5" ±0° 0' 2.5" ±0° 10'	±0° 0' 30" ±0° 0' 30" —	±0° 0' 2.5" ±0° 0' 2.5" ±0° 10'	±0° 1' ±0° 1' —	±0° 1' ±0° 1' —	±0° 1' ±0° 1' —	±0° 1' ±0° 1' —	±0° 0' 1.7" ±0° 0' 1.7" —	
RATE GYROS	PITCH YAW ROLL	±1° ROLL ±1° GYRO —	PITCH GYRO: — ±1° ±1° YAW GYRO: ±1° — ±1°														

ORBITAL ALIGNMENT REQUIREMENTS

taken at position "B" in Building 4755 (Table 2-1) that ground conditions in the area are such that a gravel bed under the pad will provide adequate support and isolation. It is recommended, however, that before proceeding with the final pad design, a test of ground stability be made at the construction site at the depth to which the ground will be excavated.

Insofar as feasible, equipment and personnel not involved in the alignment verification and dynamic testing of the PCS will be supported outside the pad area. Examples of items that should be kept off the pad during testing include the following:

- The test bay environmental enclosure
- Environmental control equipment
- Ground support equipment
- ATM access and work platforms
- Mobile equipment, such as hoists and cranes
- Personnel not required in the conduct of the test

2.4 Bending Limits

During the PCS testing, it will be necessary to move the test equipment identified in subsection 3.1.3 about the pad. The heaviest item will probably be the sun simulator, which is expected to weigh at least 1,000 lb. It will be moved from the fine-sun-sensor position near the center of the experiment package to the coarse-sun-sensor position on the edge of the Rack. Operating personnel will move with the equipment. Pad bending deflections between normals at the several equipment locations must not exceed 0.2 arc-sec. A test equipment location pattern will be made available before completion of pad design. The pad must remain stable within all prescribed limits during PCS dynamic testing, including the time when the CMGs are applying the maximum combined torque for which the system is designed.

2.5 Pad Surface Finish

2.5.1 Instrumentation Support Area

Provision will be made to insert a steel instrumentation plate (approximately 12 feet square*) and center it under the test configuration. The diagonals must be parallel with the Y and Z axes of the ATM. This plate will be grouted in and vibrated approximately flush with the surrounding area and level within ______ min. The plate must be anchored with countersunk bolts, set in a pattern that will not bring the bolt heads under the instrument feet. Provisions will be made to force grout under areas that might separate from the base during use. The thickness of the plate must be such that movement of men around the instruments will not deflect the plate more than 0.2 arc-sec. The surface of the plate will have all visible scale and pock marks removed by sanding**, then treated to prevent rust and corrosion with a material specified in the cleanroom specification. Similar plates, 4 feet square*, will be installed on two adjacent corners of the pad.

2.5.2 Concrete Surface

The pad surface outside the instrument plates must be troweled smooth in accordance with good construction practice, then treated with a nondusting material as specified for the remainder of the cleanroom floor.

2.5.3 Equipment Attachments

Provisions will be made to securely anchor the A-frame hoist rails, test stand(s) and other test equipment to the seismic pad. Anchors and mounting templates will be supplied by the agency that supplies the equipment to be mounted.

* Exact size and shape of the plates to be determined when the design of the instrument bases and instrument locations have been finalized.

** Unaided visual inspection

2.6 Stability Monitoring Equipment Support

Anchors for equipment used to monitor the pad stability will be supplied as described in other documents for installation.

3.0 Testing Procedure

The ATM alignment verification and PCS dynamic evaluation tests are a part of the integrated system test performed by R-QUAL in Building 4708. The plan for this test is currently in preparation. When published, it will provide the basis for the seismic pad final design. Pending its publication, the following test setup and procedures are assumed.

3.1 Test Setup

3.1.1 Test Stand*

During this portion of the integrated system test, the ATM will be supported on a test stand in the vertical (launch) attitude. The sun end of the experiment package will be about 8 ft above the floor. The ATM support stands(s) will be designed to dampen ATM vibration and will be rigidly attached to the seismic pad. Supports for the ATM will have micrometer adjustment for use in leveling the ATM. Load cells will also be located in the support brackets for measurement of response during dynamic testing of the CMG fine PCS.

3.1.2 Environment Verification

Functioning of the environmental control system will be verified prior to the start of PCS testing. The temperature in the test bay must be held within the specified limits for not less than 24 hr prior to start of PCS testing.

3.1.3 Test Equipment Supported on the Seismic Pad

- Test stand(s)
- Optical flats with adjustable stands (2)
- Autocollimators with adjustable stands (2)

* Not yet designed and not a part of these criteria.

- Electronic leveler
- Solar simulator
- Star simulator
- Experiment target simulators (supplied by experimenters)
- Axis alignment theodolites or other selected optics
- GSE including electrical power and support equipment

3.2 Summary of the PCS Static Alignment Verification Procedure

After all preparations have been completed, the ATM alignment will be verified, with the PCS caged, as follows:

- Verify stability of seismic pad – no quakes or storms.
- Verify that the particle count in the enclosure is safe to remove the covers of the optical instruments.
- Verify that the Rack X, Y and Z axes are mutually perpendicular and parallel with the EPS axes when caged.
- Position and electronically level an optical flat approximately under the fine-sun-sensor optical alignment target.
- Position and adjust an autocollimator under the optical flat to produce a beam vertical to the optical flat (beam should strike near center of the optical alignment target on the FSS).
- Adjust the level of the ATM at the mounting points to bring the optical alignment target on the FSS into alignment, i. e., parallel with the optical flat. Note: This optical flat and autocollimator will remain in place to monitor the FSS alignment during the remainder of the alignment verification.
- Using a second optical flat and autocollimator, position them under a selected experiment following the sequence described above. Read the deviation of the optical alignment target on the experiment.

- If the experiment is not aligned within the tolerances prescribed as determined under 1 g in Building 4755, it will be adjusted.
- The fine-sun-sensor alignment will be reverified if any adjustment of other sensors is required.
- The same process will be repeated for each experiment and the acquisition (coarse) sun sensor.
- Reverify the alignment of all experiments if significant adjustment in alignment is required on any experiment.

3.3 Dynamic Test, Experiment Pointing System

After completion of the alignment verification test, the EPS will be checked for dynamic response and stability of pointing. The following sequence is assumed:

- Verify the functional readiness of the experiment pointing control system.
- Verify electrical alignment of control and display panel.
- Remove optical collimating instruments from below ATM.
- Position the sun simulator so that the simulated solar disc is within _____ min of the center of the field of view of the fine sun sensor.
- Set experiment target simulators in specific test pattern.
- Verify the room particle count before uncovering optical systems.
- Turn on sun simulator.
- Uncage experiment package.
- Operate the experiment pointing control in Mode "A" (see Fig. 3-1).
- Observe stability of the experiment package and record deviations.
- Operate optical wedge and observe pointer response.
- Move simulated sun and observe EPS response.
- Return sun simulator to original center position.

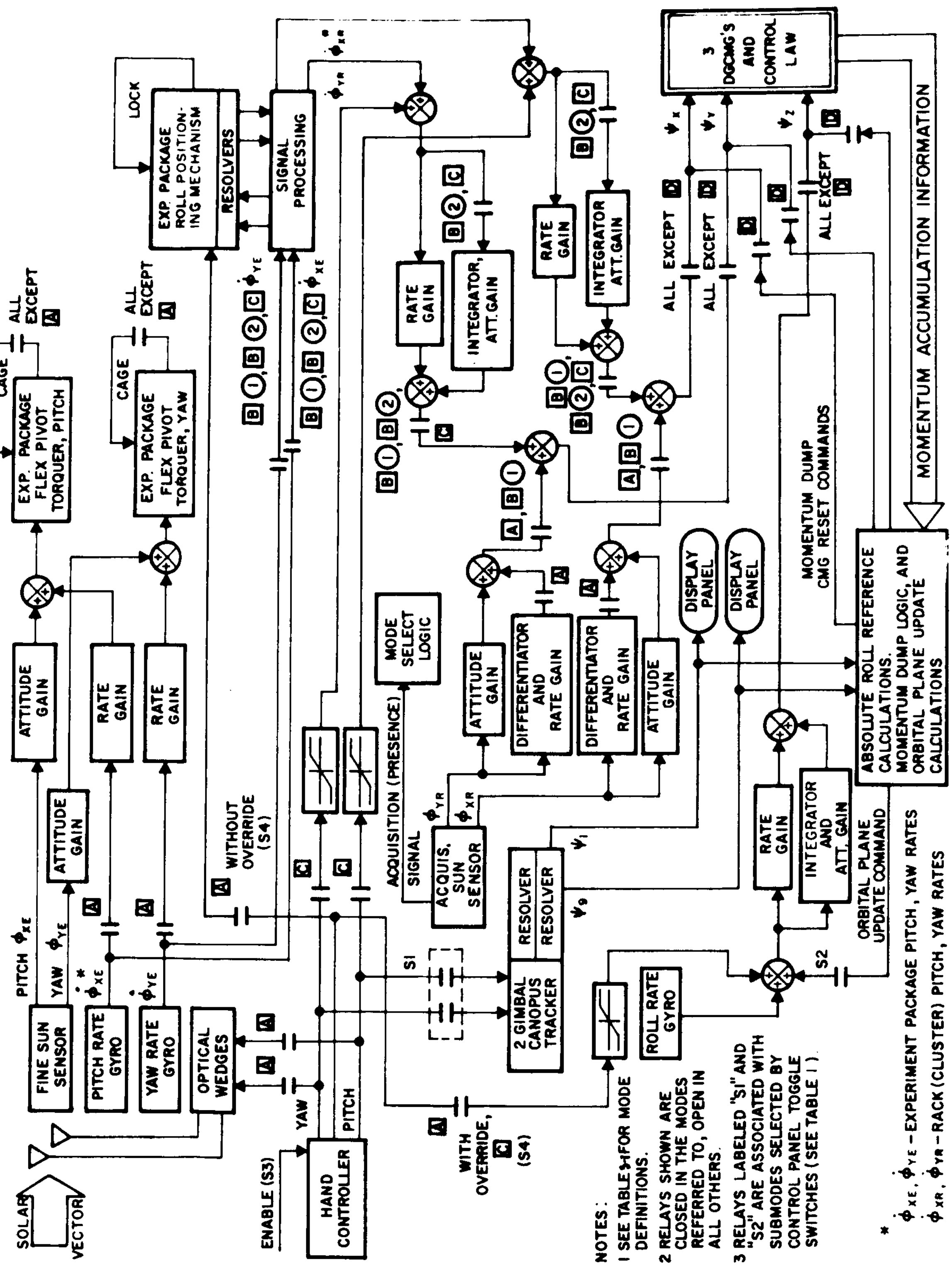


Fig. 3-1 Experiment Pointing System Schematic

- Select experiment targets for examination.
- Verify pointing accuracies of optical wedge offset.
- Operate experiments.
- Record data.
- Verify experiment alignment and true deviation readings.

3.4 Dynamic Test, ATM PCS

After verification of the EPS, the complete ATM PCS will be dynamically tested for response in modes A through D (see Table 3-1). Inputs required include:

- Sun simulation for coarse and fine sun sensors
- Star simulation
- Control commands

Table 3-1

PRELIMINARY ATM MODE DEFINITION

	MODES	VERNIER SYSTEM			FINE SYSTEM				COMMENTS
		PITCH, YAW ATTITUDE	ROLL ATTITUDE	PITCH, YAW RATE	PITCH, YAW ATTITUDE	ROLL ATTITUDE	PITCH, YAW RATE	ROLL RATE	
A	EXPERIMENT POINTING MODE	FINE SUN SENSOR ON EXPERIMENT PACKAGE, ERROR SIGNAL FROM OPTICAL WEDGE SET BY CONTROL STICK	ROLL CRANK – AROUND SET BY CONTROL STICK UNLESS OVERRIDE SWITCH IS ON, THEN ROLL CRANK-AROUND IS LOCKED	RATE GYROS	COARSE SUN SENSOR	INTEGRATE RATE GYRO UNLESS OVERRIDE IS ON; THEN INTEGRATE CONTROL STICK AND RATE GYRO	LEAD NETWORK ON OUTPUT OF COARSE SUN SENSOR	RATE GYRO	AUTOMATICALLY SWITCH TO B 2 AT CLOCK TIME
B	MONITOR AND ACQUISITION MODE — DAY	VERNIER GIMBALS CAGED AT ZERO; WEDGES ZEROED	LOCKED AT LAST POSITION	RATE GYROS ACTIVE, RESOLVED TO RACK COORDINATES	AS IN A	AS IN A EXCEPT DELETE OVERRIDE COMMENT	RESOLVED EXPERIMENT PACKAGE RATE GYROS	AS IN A	AUTOMATICALLY SWITCH TO NIGHT SIDE HOLD 2 AT CLOCK TIME
	NIGHT 2	VERNIER GIMBALS CAGED AT ZERO, WEDGES ZEROED	LOCKED AT LAST POSITION	RATE GYROS ACTIVE, RESOLVED TO RACK COORDINATES	RESOLVED INTEGRATED EXPERIMENT PACKAGE RATE GYROS	AS IN A EXCEPT DELETE OVERRIDE COMMENT	RESOLVED EXPERIMENT PACKAGE RATE GYROS	AS IN A	AUTOMATICALLY SWITCH TO 1 AT CLOCK TIME
C	INERTIAL HOLD AND MANEUVER MODE	VERNIER GIMBALS CAGED AT ZERO, WEDGES ZEROED	LOCKED AT LAST POSITION	RATE GYROS ACTIVE, RESOLVED TO RACK COORDINATES	RESOLVED INTEGRATED EXPERIMENT PACKAGE RATE GYROS, AND/OR CONTROL STICK	INTEGRATE RATE GYRO, AND/OR CONTROL STICK	RESOLVED EXPERIMENT PACKAGE RATE GYROS	AS IN A	
D	MOMENTUM DUMP MODE	AS IN C	AS IN C	AS IN C	AS IN B 2	AS IN B 2	AS IN B 2	AS IN B 2	ATTITUDE ERROR SIGNALS TO CMG SYSTEM OPEN

4.0 Activation

4.1 Hardware Delivery Schedule

The date of delivery of the thermal/mechanical test unit to Building 4708 will determine the need date for the test facility. This is currently scheduled for May, 1968. Indications are that this date will be changed to November, 1968. The latter date is assumed in these criteria.

4.2 Facility Design

A period of 3-1/2 mo is proposed in which to conduct soil tests, complete the engineering design, advertise, receive bids and award a contract. This span assumes no delay in the availability of design parameters.

4.3 Construction Time Span

Removal of the present floor, excavation, and construction and curing of the seismic pad will require 2-1/2 mo. This assumes no more than 10 days delay due to causes not under control of the contractor.

4.4 Equipment Installation and Checkout

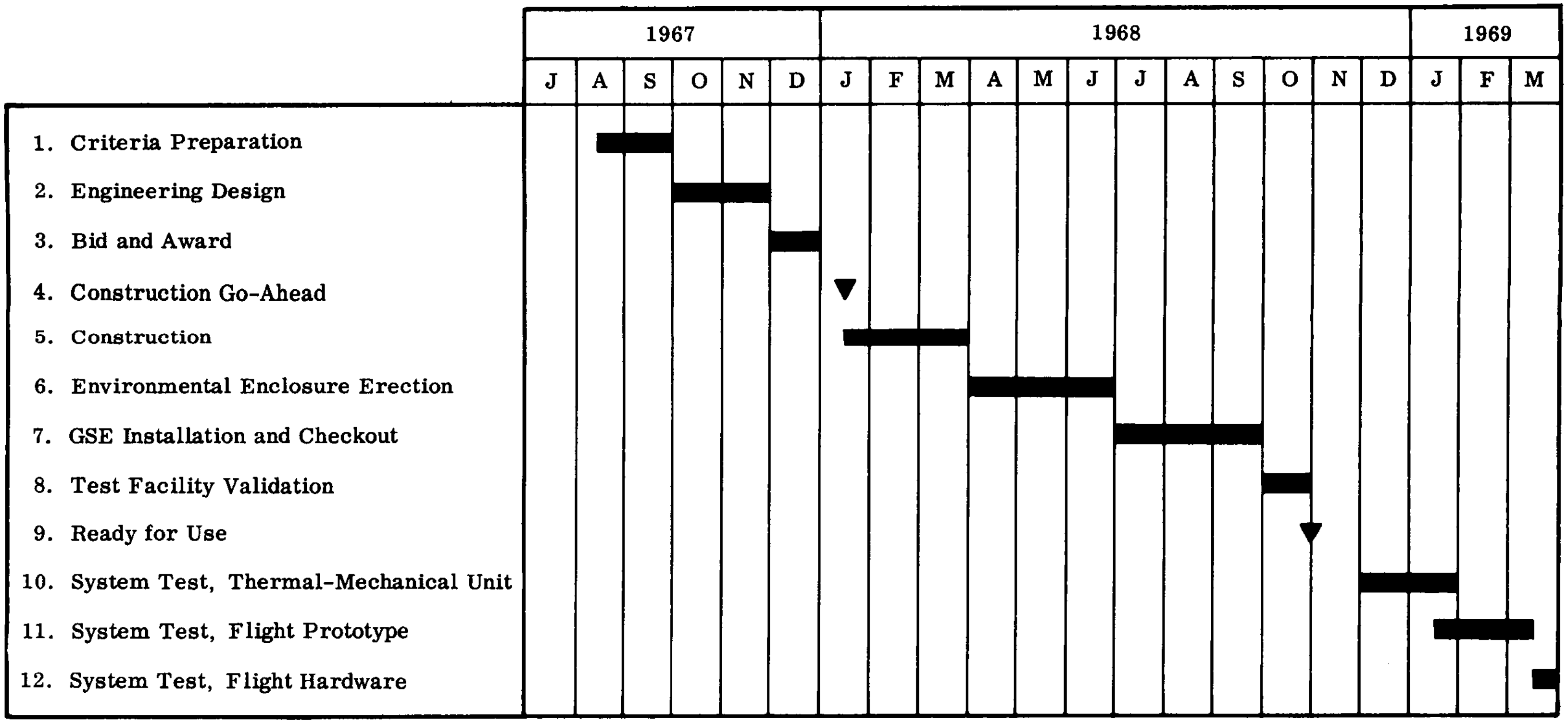
A period of 6 mo. is alotted for this acitvity. It covers those tasks performed that are not a part of the seismic pad contract, but are required to complete the test facility including construction of the environmental enclosure and installation and checkout of the test equipment.

4.5 Acceptance

Upon completion of pad construction and equipment installation, a validation test of the facility will be performed to determine that the facility, including the seismic pad, meets all design specifications. Successful completion of this test will be the basis for acceptance of the seismic pad.

4.6 Proposed Schedule

Figure 4-1 is a proposed schedule covering the design, construction and acceptance of the seismic pad. Activities other than those involved in the pad construction which determine set-back dates are shown for reference only.



Note: Schedule based on current Program Office estimates of hardware availability

Fig. 4-1 Design, Construction, and Acceptance Schedule

5.0 Abbreviations and Definition of Terms

AAP	Apollo Applications Program
ATM	Apollo Telescope Mount
C. G.	Center of gravity
CMG	Control Moment Gyro
CSS	Coarse Sun Sensor
ESE	Electrical Support Equipment
EPS	Experiment Pointing System (that portion of the PCS formerly called the Vernier Pointing System that controls the pitch and yaw attitudes of the experiment package.)
FSS	Fine Sun Sensor
GSE	Ground Support Equipment
Hz	Cycles per second
LM	Lunar Module
PCS	Pointing Control System
RCS	Reaction Control System
SLA	Saturn – LM Adapter

Seismic Pad

These criteria do not describe a true seismic pad according to the dictionary definition. An isolation pad would be a more correct term. Seismic pad is used, however, since the task was defined before the requirements were more fully known.

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TASK 38C

POINTING CONTROL SYSTEM TEST AND CHECKOUT GUIDELINES

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1.0 Introduction

1.1 Purpose

The Pointing Control System (PCS) Test and Checkout Guidelines will provide a detail method for management control of testing and ensure a logical achievement of program goals. This plan will establish the extent of testing to be performed and will delineate those test procedures necessary to meet the requirements of the ATM Project Requirements Document and the ATM System Specification.

1.2 Scope

The PCS Test and Checkout Guidelines will provide those plans necessary to qualify and accept a flight system. This plan covers all major activities, relationships and requirements for the testing and support of a non-flight and flight PCS.

1.3 Project Description

1.3.1 General Description

1.3.1.1 Pointing Control System

The Pointing Control System (PCS) for the ATM will consist of a Control Moment Gyro Control System (CMGCS) and an Experiment Pointing System (EPS). The CMGCS will provide attitude control for the entire cluster. The EPS will provide vernier pointing control for the experiment package.

1.3.2 Pointing Control System Assembly

The Apollo Telescope Mount (ATM) consists of a carrier spacecraft to which is attached a gimbaled spar containing optical equipment for performing solar astronomy experiments from orbit. The carrier may be either the ascent stage of the Lunar Module (LM) or this vehicle docked to an aggregation of other flight modules, principally the Command and Service Modules (CSM) and the S-IVB stage of the Saturn booster. The latter Configuration is called the Cluster. The carrier is actuated for attitude control by three control moment gyros (CMG's) and a Reaction Control System. The spar is actuated by torque motors mounted between the gimbal system and a Rack attached to the LM. Two of the gimbal axes (pitch and yaw) are hinged on flexure pivots. The third axis (roll) is not controlled other than for being moved from one fixed orientation to another.

The Pointing and Control System performs the following functions:

a. Maintain Cluster control without CMG momentum dumping more than once per orbit.
b. Utilize minimum RCS fuel (none during daylight period).
c. Stabilize Cluster during experiment period within capability of vernier pointing system and star tracker.
   1. Pitch & Yaw less than 0.1 degree range and 1 arc min/sec maximum rate.
   2. Roll less than 7.5 arc min during daylight period and 1 arc min/sec maximum rate.
d. Provide pitch and yaw position of the experiment package with a resolution of 1 arc sec over ± 30 min of arc with respect to the solar center.
e. Provide roll position of experiment package with 10 arc min accuracy over ± 95 degrees.
f. Provide absolute solar pointing orientation of ± 2.5 arc sec in pitch and yaw and 10 arc min in roll.

g. Manual operation can improve absolute pointing accuracy.

h. Stabilize experiment package in pitch and yaw within ± 2.5 arc sec over the daylight period.

i. Maintain jitter rate less than 1 arc sec/second in pitch and yaw and 1 arc min/sec in roll.

1.3.2.1 <u>Inputs to ATM from LM</u>

Offset Pointing Commands
- o Pitch
- o Yaw

Astronaut Manual XMTR Roll Angle
- o Roll

Star Tracker Bias Angle

Astronaut Manual XMTRS Rack Attitude
- o Pitch
- o Yaw
- o Roll

Gravity Gradient Momentum Dump Enable

Manual Gimbal Bias XMTR
- o Inner
- o Outer

Momentum Dump Switch
- o Inner
- o All

1.3.2.2 <u>Outputs from ATM to LM</u>

Astronaut Display Spar Attitude
- o Pitch
- o Yaw
- o Roll

Astronaut Display Rack Attitude Error

Gimbal Angle Display
- o Inner
- o Outer

Stored Angular Momentum Display

- o H_1, H_2, H_3, H_T

Reaction Control Network

- o Pitch
- o Yaw
- o Roll

1.3.3 Functional Subassemblies

1.3.3.1 Control Moment Gyro Control System (CMGCS)

The Control Moment Gyro Control System will provide for:

a. Solar acquisition

b. Automatic attitude hold operation

c. Astronaut manual operation

The CMG Control System will consist of 3 control moment gyros (CMG's), 3 rate gyros (the pitch and yaw gyros will be mounted on the experiment package and the roll gyro will be mounted on the rack), a star tracker, a solar acquisition sensor (coarse sun sensor) and elements of the PCS electronics assembly. After docking to the Multiple Docking Adapter (MDA), CMG wheels will be spun up with predetermined gimbal angles. When CMG gimbal angles approach their limits during operation, the Service Module Reaction Control System (SM RCS) will be used for unloading the CMG's. The SM RCS will also be used for this purpose during periods when the LM/ATM is operated docked to to the MDA. For LM/ATM free flight operation the LM RCS will perform this function. Passive techniques are being studied as an alternate means for desaturating CMG's and thereby reducing RCS propellant expenditures. In order to maximize solar observation time, the CMG momentum unloading will occur during the Earth shadow phase of the orbit. The momentum storage capacity of each CMG is

2000 ft-lb-sec. A primary input for coarse pointing will be from the sun sensor. Pointing during daylight phases will be achieved within a accuracy of $\pm 0.1^{\circ}$ for pitch and yaw and ± 7.5 arc minutes for roll. An inertial hold mode will be provided to keep the system aligned during the darkness phase of the orbit. The primary sensor inputs for this mode will be the rate gyros and the star tracker.

1.3.3.2 Experiment Pointing System (EPS)

The Experiment Pointing System will provide the following capabilities for the experiment package:

a. Fine solar acquisition

b. Offset pointing

c. Automatic attitude hold operation

d. Astronaut manual operation

This system will consist of the experiment package's gimbal suspension assembly, gimbal torquing actuators, pitch and yaw rate gyros, an experiment package roll positioning device, a fine sun sensor, experiment package pointing control television and associated pointing control equipment and elements of the PCS electronics assembly. The Experiment Pointing System will be capable of moving the experiment package $\pm 95^{\circ}$ in roll using the roll positioning device and $\pm 3^{\circ}$ in pitch and yaw using the gimbal torquing actuators.

The Experiment Pointing System will provide the following experiment pointing accuracy for at least 15 minutes per orbit:

a. Pitch and yaw: $\pm$ 2.5 arc seconds

b. Pitch and yaw jitter rate: $\pm$ 1 arc second per second of time

c. Roll: $\pm$ 10 arc minutes

d. Roll jitter rate: $\pm$ 1 arc minute per second of time.

1.3.4.. Major Components

1.3.4.1 Control Moment Gyro Control System

Acquisition Sun Sensor

Star Tracker

Control Moment Gyros

Electronics

Controls

1.3.4.2 Experiment Pointing System

Fine Sun Sensor

Gimbal System

Electronics

Rate Gyros

1 3.5 Mode Control

The various modes of operation of the control systems are described with the assumption that the spacecraft is in an initial arbitrary attitude in space following injection into orbit. At first the Spar will be rigidly locked to a neutral position within the Rack by means of a mechanical caging device. The mechanical cage will be maintained until the Rack has been oriented to the desired attitude, which consists of pointing roughly at the sun while maintaining a roll reference using the star Canopus. The basic, or inner loop, reference for carrier attitude is provided by three body-mounted single-degree-of-freedom rate integrating gyros. Each gyro is provided with electrical feedback from its signal generator to its torquing amplifier to enable caging for the target hold mode.

Gross orientations are performed by using manual signal transmitters to torque the uncaged gyros. Signals from the gyros are applied through compensation and deadband circuits to the reaction jet valves and nozzles. The same gyro signals are processed to CMG control signals. Since the CMG control signals are applied directly to the CMG's while the reaction jet signals are passed through a deadband circuit before being applied to the reaction jet valve drive amplifiers, it is clear that the CMG's will act as a vernier moment generating system within the deadband of the reaction jet system. When the CMG's are not capable of handling a particular disturbance they will overload, that is, drive to their gimbal limits or drive to an orientation where their spin axes are parallel. When this occurs, the RCS system is called into play. The RCS system is, of course, always called into operation whenever the error signal is outside the RCS deadband.

Initial acquisition consists of locking the Spar to the Rack and then manually driving the vehicle roll axis to rough alignment with the sun line. When manual control has brought the vehicle roll axis sufficiently near the sun line, the "sun presence detector" in the sun sensor will produce a signal used to actuate the MAN-AUTO relay to automatic. Signals proportional to angular deviation from the sun line, developed within the sun sensor, are then applied through the relay to torque the uncaged gyros. This procedure, slaves the pitch and yaw axes of the ATM carrier to the sun line.

During the periods of occultation of the sun, the absence of a signal from the "sun presence detector" releases the relay, and attitude reference reverts to the gyros alone. The gyros will hold the vehicle so that the sun, when next seen, is within the field of view of the acquisition sun sensor. Thus, the sun will be automatically reacquired each time it reappears.

1.3.5.1 CMG Momentum Dumping

When the LM/Rack is operated with the Cluster configuration oriented to point the Rack to the sun, large aerodynamic and gravity gradient torques cause angular momentum to be accumulated by the CMG's. These are for the most part cyclic torques, for which the average change in angular momentum is zero. One component of the gravity gradient torque is not cyclic, and certain deviations of the Cluster from a cylindrical geometry can result in unidirectional components of aerodynamic torque. Also, magnetic torques may exist whose average value is not zero. Consequently, angular momentum is accumulated and must be dumped periodically.

The gravity gradient method can be implemented as an automatic adaptation of the control system and requires only small changes from the nominal flight mode for momentum control. These may be made when the spacecraft is on the dark side of the orbit and the ATM is not operating, or they may be made throughout the orbit with the vernier gimbal control system correcting for the pointing errors they produce.

Provision is made for either manual or automatic momentum dump. In the manual mode, the astronaut is required to monitor all CMG gimbal angles and the magnitude of the stored angular momentum (alarm buzzers or lights can be provided to warn of an impending limited gimbal). At any desired time, the astronaut may depress a spring-loaded momentum dump switch, which operates a relay at the input to the CMG torquing amplifier. When the relay is actuated, the CMG is electrically reset (or caged) by feeding a signal from the gimbal angle pickoff back to the torque amplifier. The torquer will then drive the CMG gimbals involved to a position determined by the manually set "bias control" (which may be zero).

If automatic momentum dump operation is desired, the mode select switch is set to "AUTO." This action puts into the circuit a special level sensor device which operates as follows: As a gimbal is driven to its limit in either direction, the level sensor produces a zero signal until a point just short of the mechanical limit stop is reached. At this point the level sensor produces a signal which closes the CMG caging relay. Although the CMG gimbal begins to drive toward null, because of caging action, the level sensor, because of built-in hysteresis, continues to produce a signal until a point close to the preset bias is reached. Thus, when the Rack is subjected to an average unidirectional disturbance torque, the appropriate CMG gimbals will be driven in a direction to oppose the disturbance. When a gimbal limit is reached, the caging relay will be automatically actuated by the level sensor and will be held in until the caging loop has brought the CMG gimbal back to null. The general effect will be to cycle around one side of the level sensor hysteresis characteristic, moving outward under the action of the external disturbance torque and moving inward under the action of the caging loop.

Caging of a single CMG may result in the torque's being absorbed by the other two CMG's or in the reaction jets being actuated. A similar level sensor senses the magnitude of the total angular momentum stored by the CMG's. When this value approaches saturation, all CMG gimbals are caged and held in the caged mode by hysteresis in the sensor until they are near a preselected condition of zero stored angular momentum. This action always causes the carrier to be rotated to the limits of the reaction control deadband, and the jets provide impulse to dump the momentum from the CMG's.

1.3.5.2 Experiment Pointing System

The Spar possesses its own attitude control system to permit the extremely fine pointing accuracy required by the telescope. Pitch and yaw deviations from the sun line are sensed by a precision sun sensor capable of tracking the center of the sun. This sensor is provided with manually controllable optical wedges in its field of view to permit offset pointing. It will be remembered that the Spar is locked within the Rack during initial attitude acquisition. When the entire vehicle has been brought to the proper sun-Canopus orientation, and the Rack is in the automatic attitude hold mode, the Spar-Rack locks are de-energized and fine pointing takes place. Signals from the precision sun sensor located on the Spar are fed to torque amplifiers, which drive pitch and yaw gimbal torquers. Moments are developed by the torquers, which are mounted on the gimbals holding the Spar to the Rack. Thus, the Spar is pointed in a vernier manner by being torqued against the inertia of the Rack. The resulting disturbances in the Rack are absorbed by the previously described CMG system. Rate dumping is provided by two precision rate integrating gyros.

No independent automatic roll control system is provided to the Spar. Primary roll reference is obtained from the Canopus sensor on the Rack. However, the Spar does have a roll freedom within the Rack. Spar roll is controlled manually by the astronauts and referenced by a precision roll angle pickoff between the Spar and Rack. During periods of sun occultation the Spar gimbal torquers are electrically caged, with signals fed back from gimbal angle pickoffs to the corresponding torquer amplifier. Hence, a vernier pointing mode acquisition is required each time the sun is initially acquired. This requirement presents no particular problem since the sun will be in the field of view of the precision sun sensor although not on the null.

Ultimate pointing is achieved by means of the manually controllable optical wedges. The results are observed through a bore-sighted vidicon sun viewer.

1.3.5.3 Roll Reference

The proposed reference for roll about the sun line is a Canopus tracker mounted on the Rack. Figure 1-1 shows the geometry of the ATM in orbit when the LM is docked to the Cluster. The flight mode is assumed to be one that keeps the longitudinal axis of the Cluster nominally in the orbit plane. This is required to minimize large unidirectional torques, which would act with this axis out of the orbit plane. The Cluster remains essentially fixed relative to the sun, with the CMG's absorbing and releasing

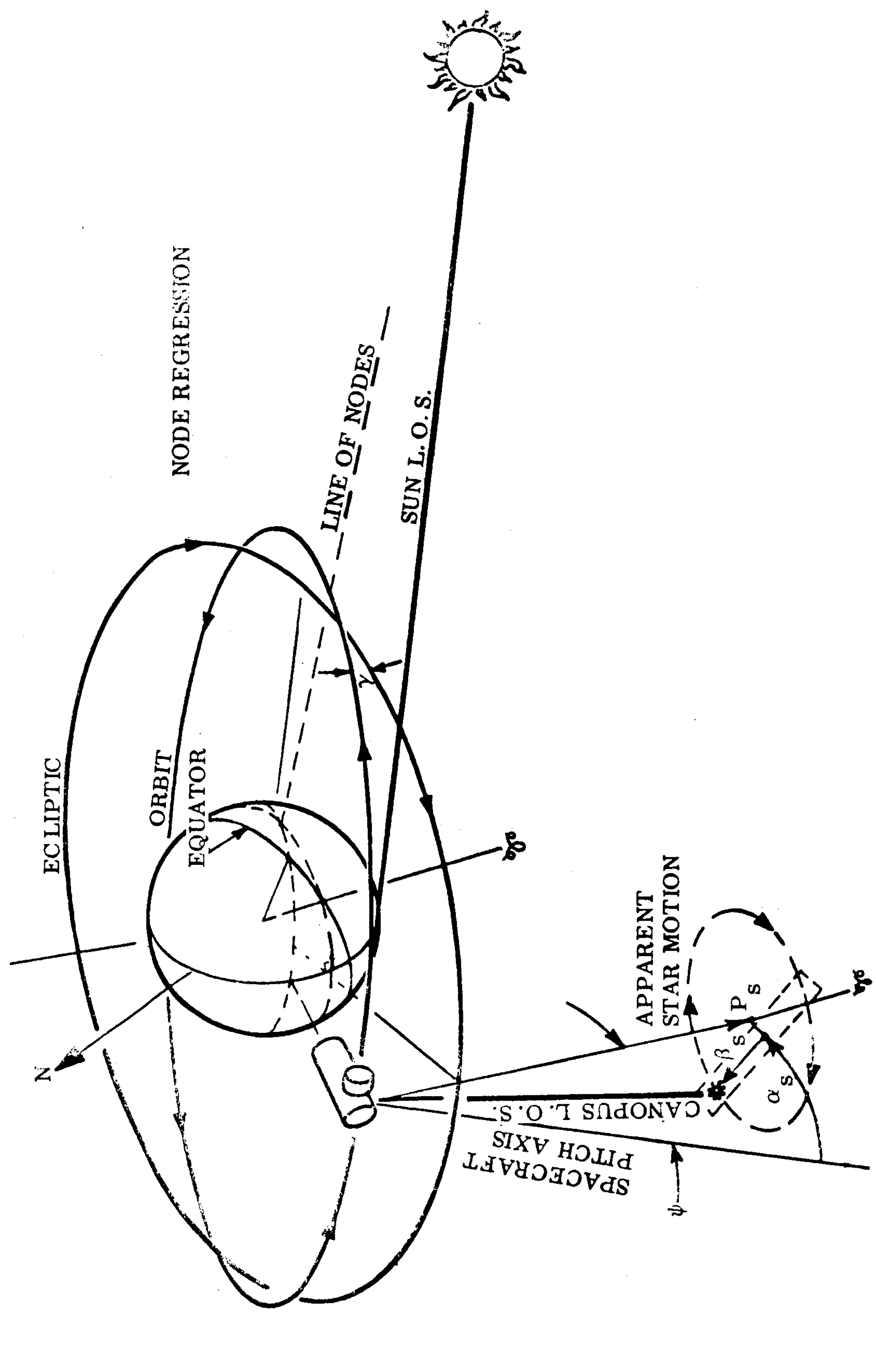


Fig. 1-1 Roll Sensing Geometry

the cyclic angular momentum accrued from the gravity gradient torques acting in pitch.

To accommodate the flight mode, the tracker must be gimballed through $\pm$ 67 deg. on one axis (the outer) and $\pm$ 15 deg. on the other (the inner) to maintain a view of Canopus. The orbit is assumed to have an inclination, i, of 28.5 deg relative to the equator. Its line of nodes relative to the ecliptic regresses at a rate of about 6.5deg/day, causing the angle α_s in the figure to move through the $\pm$ 67 deg. As the earth revolves about the sun, the line of sight to Canopus appears to rotate about the direction to the south celestial pole at a rate of one revolution per year, causing the angle β_s in the figure to move through $\pm$ 15 deg.

The angle α_s is computed and used to bias the signal from one gimbal of the star tracker. The difference between this gimbal angle and α_s is used as the roll reference for the Cluster control system. Since α_s varies, it must be updated from time to time. The frequency of updating and the accuracy of its computation are not critical, however, since a slight deviation of the longitudinal axis from the orbit plane is tolerable.

The roll angle of the spar is referenced to the Rack by a precision angle pickoff, as is the gimbal angle on the star tracker, which moves in the direction of α_s. The difference between the angles gives a precise measure of the spar's roll angle relative to inertial space if only the time of year is known. The precision of this measurement is limited by the accuracy of the angle pickoffs on the spar and tracker gimbal; these pickoffs can conveniently be made less than 10 arc sec. The line of sight to Canopus becomes occulted by the earth during a part of each orbit. A Canopus presence detector removes the signal from the star tracker, leaving the CMG's to maintain attitude on the basis of the roll gyro, which is continuously torqued to the required orientation by the signal from the star tracker when Canopus is in view. To facilitate automatic reacquisition of Canopus after occultation, the Canopus presence detector will also actuate a lock to cage the tracker gimbals during the period of occultation.

1.4 Test Program Summary

1.4.1 General

The Acceptance Test Program conducted on the Pointing Control System (PCS) shall consist of Post Manufacturing Tests, Vibration Tests and Thermal Vacuum Tests. The PCS post manufacturing tests shall be performed in building 4708 at MSFC in the to be constructed alignment station. The vibration tests will be performed at P&VE of MSFC. This test will verify that the system will withstand the launch environment. The thermal and vacuum test (TV) will be performed at (facility location not established) and will consist of the operation of the PCS in a TV chamber. The primary purpose of this test will be to determine any arcing or corona effects between the components of the integrated system, adequacy of the thermal control techniques utilized, degradation of materials due to effects of a high vacuum and solar radiation, hot and/or cold spots in equipment, cold welding of moving parts and sealing of pressurized components.

1.4.2 Definition of Tests

1.4.2.1 Acceptance Tests -- These tests conducted at the factory will constitute customer acceptance of each End-Item Assembly. A detailed Acceptance Test Procedure (ATP) will be prepared in accordance with NPC 200-3. The acceptance tests to be performed will be the following:

a. Size and mounting provision

b. Weight

c. Input characteristics

d. Output characteristics

e. Power consumption

f. Accuracy

g. Grounding

h. Calibration

i. Phyiscal appearance

j. Environmental tests

Test Procedure Approval -- The contracting agency's preliminary approval of an ATP is required prior to the onset of acceptance testing. The approved version shall embody the contractor's design criteria as applied to acceptable test limits. Final approval of ATP's, which shall incorporate any changes resulting from qualification testing, is required for the contracting agency's acceptance of flight units. ATP data sheets shall be included as part of the Equipment Log.

1.4.3 Equipment Log

The Contractor shall submit an equipment log for each component of the Pointing Control System

1.4.4 Environmental Summary

In general, the environmental levels for acceptance testing shall not be less than the expected environmental conditions to be experienced in its application to a mission.

1.4.5 Standard Test Conditions

Standard test conditions are room ambient conditions of temperature, humidity, and atmospheric pressure. Actual ambient test conditions shall be recorded during the test.

Whenever these conditions must be closely controlled in order to obtain reproducible results, a reference temperature of +70°F, a relative humidity of 35%, and an atmospheric pressure of 30 inches of mercury shall be used, together with those tolerances required to obtain the desired precision of measurement.

1.4.5.1 Tolerances -- The maximum allowable tolerance on test conditions shall be as follows:

a.	Temperature	High	±5°F
		Low	+0°F -10°F
b.	Altitude		± 5%
c.	Relative Humidity		+3% -2%
d.	Vibration Amplitude		± 10%
e.	Vibration Frequency		± 2%
f.	Time durations		± 5% (generally)

g. Additional tolerances -- Additional tolerances shall be specified.

1.4.6 Test Approval

All facilities, equipment, tests, and procedures required for testing the PCS shall be approved by the Contracting Agency prior to initiation of the test program. Testing conducted by either contractor or an approved laboratory shall be performed in the presence of or approved by the Contracting Agency designated - responsible inspection representatives.

1.4.7 Test Surveillance

Notification of the location of tests and of the time such tests will be initiated shall be supplied to the Contracting Agency as soon as practicable, but no less than 48 hours in advance of the start of the tests. No testing shall begin prior to approval of the test procedure.

1.5 Applicable Documents

A. Marshall Space Flight Center Project Development Plan (PDP) for Apollo Telescope Mount, dated 13 April, 1967.

B. Test Program Guidelines for ATM, MSFC 50M02407, 1/25/67.

C. Apollo Applications Test Requirements (when published).

D. SP-6001, Apollo Terminology.

E. MSFC Procedure 239.3A Test Procedure Preparation.

F. MIL-STD-831 Test Report Preparation.

G. ATM System General Specification MSFC No. ______________.

H. Apollo Applications Program General Test Plan for Apollo Telescope Mount Project MSFC 50M02410 dated 21 April, 1967.

I. Preliminary Criteria -- Seismic Pad, Bldg 4708, for Alignment Verification Test, Apollo Telescope Mount.

2.0 Summary of Major Test Program Policies and Requirements

2.1 General

The overall ground testing concept must yield maximum confidence that the hardware will operate as required in the prescribed environment through the mission duration. All PCS system testing activity shall be controlled by the ATM General Test Plan. The test program shall cover all testing required for the PCS including design evaluation, manufacturing process qualification, acceptance and pre-launch activities. The test plan shall also establish the general requirements for preparation of detailed test documentation. The following guidelines shall be utilized in developing the PCS test program:

a. The PCS test program consisting of development, qualification, acceptance, integration, and reliability testing shall be closely interwoven to make maximum utilization of test hardware.

b. All tests shall be performed at the highest hardware generation level practical with minimum piece part testing.

c. Complete acceptance tests shall be conducted at the origin of manufacture where possible to reduce duplicate testing.

d. Existing resources shall be utilized where practicable (facilities, equipment, procedures, data and personnel.)

e. Results of other programs shall be utilized where possible and only the delta between the programs shall be tested.

f. Requalification shall be minimized.

2.2 Development Testing (Reference)

Development tests shall include tests required to evaluate and optimize the ATM design, and shall be performed to establish a configuration complying with mission requirements.

Ultimate objectives shall be to identify design weaknesses and to identify areas of performance degradation to permit early optimization of design. Evaluations on hardware performance under simulated or actual environmental conditions shall be conducted. Tests include engineering evaluation of components and subsystems, systems compatibility and the total system.

Development tests shall be concerned with areas where present qualification data are unavailable, or inadequate, and additional information regarding various materials and processes is necessary to proceed with a design. Modifications and fixes resulting from testing failures shall be documented and incorporated as design changes.

Developmental testing shall encompass static structure vibration thermal-vacuum, temperature shock, acceleration and EMC.

2.3 Qualification Testing (Reference)

Qualification testing shall be conducted on all unqualified components, subsystems, and systems. Engineering judgment shall determine extent and degree of testing necessary to insure fully qualified flight articles. In most cases, the tests and test levels will be the same as those used during the developmental testing phase. Qualification testing shall confirm the hardware's ability to perform (structurally and functionally) within the mission environment. Units to be subjected to qualification testing shall be flight configurations.

2.4 Acceptance Testing

Acceptance testing shall be an integral part of production activities. The test program shall confirm that manufacturing operations have been accomplished in accordance with engineering documentation; that the tested items have met all design criteria and intent; and that tested items interface physically and functionally with other flight and ground support equipment items.

Acceptance testing shall normally be conducted at the manufacturing site, although acceptance testing will be conducted until vehicle launch. Test articles for qualification testing will be subjected to specific acceptance tests.

Acceptance Tests will be conducted by the contractor prior to shipment of each PCS subsystem to prove compliance with the performance requirements of its specification. These tests shall be performed in accordance with NPC 200-3 and shall be the following:

2.4.1 Post Manufacturing Examination

Each PCS subsystem shall be examined for conformance to the requirements of its specification for workmanship and marking, and to the applicable drawings.

2.4.2 Post Manufacturing Test

Each PCS shall be tested to demonstrate compliance with the performance requirements of its specification under normal operating conditions prior to exposure to the acceptance (Vibration & Thermal Vacuum) tests.

2.4.3 Acceptance Environmental Tests

Each PCS shall meet the performance requirements of its specification while subjected to the following environmental conditions unless otherwise specified. The pre and post-environmental performance shall be conducted each time the Acceptance Environmental Tests are performed.

Nonoperating Tests

Vibration

Operating Tests

Thermal-Accuracy

(Performance during thermal exposure) - Tests shall be conducted to demonstrate that the PCS meets the requirements of the Acceptance Test Specifications over the defined temperature extremes. These tests shall be conducted under steady state thermal conditions.

Leak Tests

(Before and after environmental exposure) - Pressurized systems shall be tested for leaks to the requirements specified in ____________.

2.4.4 Post-Environmental Performance Tests

Upon completion of all environmental testing, the PCS shall be subjected to tests to the extent necessary to assure that environmental testing has not caused degradation of performance.

2.4.5 Acceptance Test Data and Reports

All acceptance test data and reports shall be in accordance with NPC 200-3.

2.5 GROUND SUPPORT EQUIPMENT

2.5.1 General

The Ground Support Equipment (GSE) shall contain provisions necessary to checkout, service and handle the PCS subsystems and system at the technical support and operations areas. Systems test will be conducted at MSFC (Bldg. 4708). Vibration testing will be conducted in the P&VE' laboratory. Thermal vacuum testing will be performed at a site to be determined.

Two sets of Electrical Support equipment (ESE) will be built. Both the prototype unit and the flight unit will be tested at MSFC concurrently. Experiment checkout equipment (ECE) will be supplied by the principal investigators. The ESE will be supplied by MSFC. The ESE will be used for overall system testing and the ECE will be used by the principal investigators for experiment testing, calibration and maintenance.

2.5.2 Support Equipment Functional Requirements

2.5.2.1 Post Manufacturing Testing

Testing on the PCS will be performed in building 4708 using a manual ESE. Each set of manual checkout equipment will comprise approximately 30 racks of equipment. Space requirements will consider equipment placement and personnel accessibility for operation and maintenance.

Two areas are required, each of 700-1000 square feet, for a total requirement of 1400-2000 square feet. It appears that Bldg. 4708 at MSFC has sufficient space available to handle this requirement. Modifications to the area will be necessary but cannot be identified at this time. If the two (2) planned sets of ESE are installed in Bldg 4708, hardline cabling will be necessary to the P&VE Lab to enable the performance of the vibration testing at that location. An alternative to this would be to move the set of ESE from Bldg 4708 to the P&VE Lab upon completion of the systems test and prior to performance of the vibration test.

Approximately 3-½ tons of refrigerated air conditioning will be needed for each set of ESE to provide temperature control of the electronic equipment. This estimate is based on similar systems presently used for system testing. An alternate approach is to install the ESE into trailers. A mobile, trailerized system will require three (3) trailers approximately 35 feet long. This will provide 700 square feet of space for each set of ESE.

2.5.2.2 Vibration Testing

The ESE to be used for the vibration testing in the P&VE area will be transported by trailer to the P&VE building. Parking space of 1000 square feet and power outlets of 15,000 watts of 110/208 Volt 3 phase 60 Hz will be required.

2.5.2.3 Thermal Vacuum Testing

The proposed method of supporting the TV system test is by relocating a checkout system to the test facility during the testing program. This would permit the use of the ESE for both the prototype and flight article at the thermal vacuum facility. A test stand permitting a vertical, front up orientation of the ATM will be required at the TV facility.

2.6 Test Documentation

2.6.1 Acceptance Test Plan

The acceptance test plan shall contain the general acceptance test requirements, including the tests to be conducted, environmental extremes and exposure durations, and the PCS parameters to be measured before, during, and after each Thermal Vacuum & Vibration test.

2.6 2 Acceptance Test Procedure

An acceptance test procedure shall be written by the testing agency prior to the start of acceptance testing. The acceptance test procedure shall contain the detailed, step-by-step procedure for implementation of the acceptance test plan. The acceptance test procedure shall contain detailed descriptions of the environmental test chambers, the test equipment to be used in conducting functional tests (including manufacturer's model numbers for standard instrumentation) and diagrams of test setups.

2.6.3 Acceptance Test Report

An acceptance test report will be submitted by the testing organization at the conclusion of acceptance testing. The test data will be compiled as a report with a discussion of failures, changes, and retesting.

2.6.4 Failures

An acceptance test failure shall be defined as the inability of the PCS to meet any of the requirements of its specification in any phase of acceptance testing.

2.7 Logistics Requirements

Logistics support requirements shall be based on systems analysis, maintenance analysis of hardware, and end item and site logistics requirements summaries. Logistics support shall be provided for both flight hardware and GSE by the contractor for PCS hardware.

The required logistics support elements shall include:

a. Spares Provisioning

b. Inventory Management

c. Maintenance

d. Technical Support Data

e. Transportation/Packaging

3.0 Test Environment Requirements

3.1 General

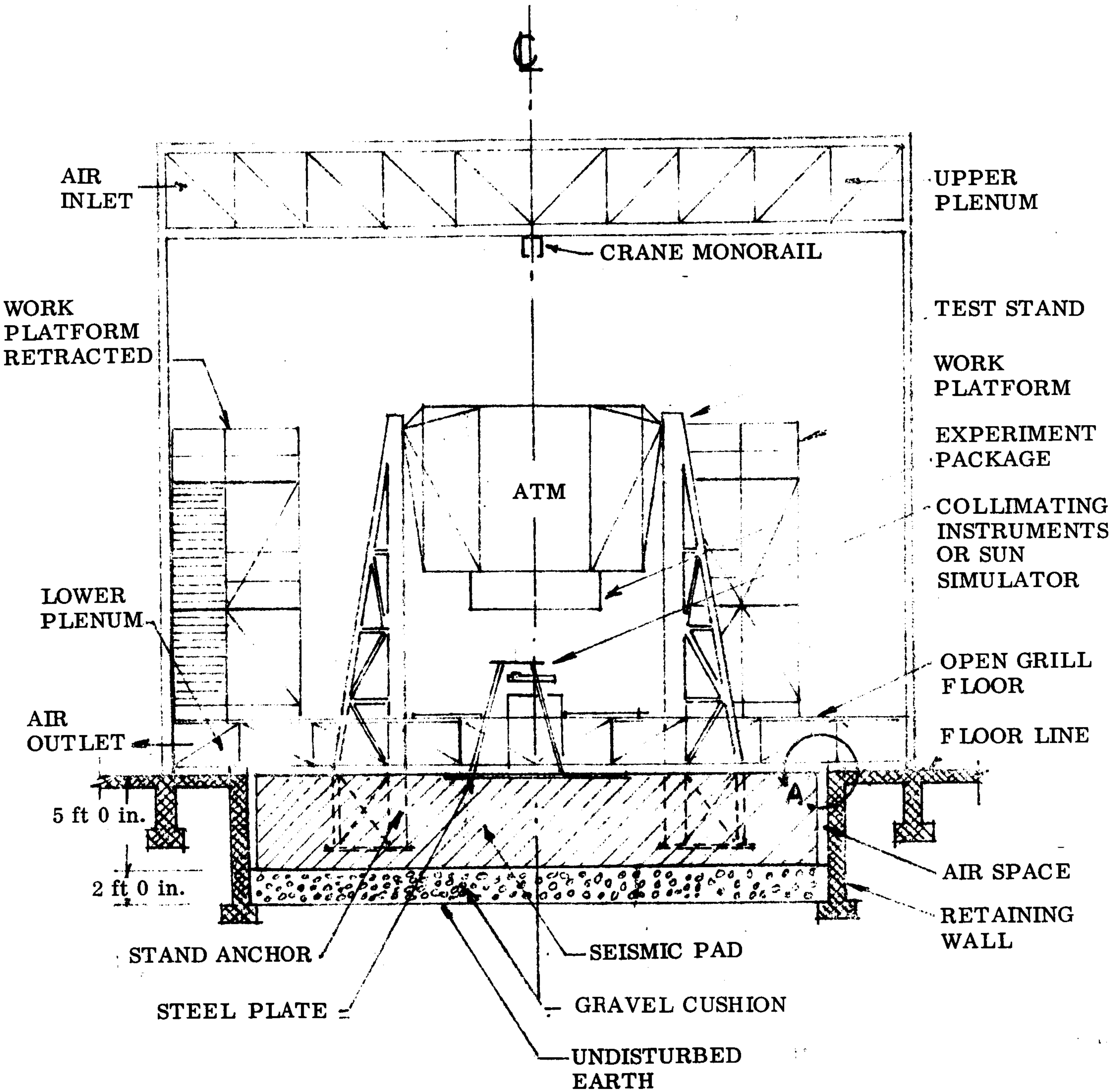
The environments required for the testing of the PCS system will be supplied by an environmental enclosure and test stand in Bldg. 4708. This test stand and Seismic pad will be in an enclosed area which is environmentally controlled to a class 10,000 clean room Federal Standard 209a during the test. This enclosure and environmental control system will be of the laminar flow type entering at the top and exhausting thru the floor. The temperature shall be 70°F ± 5°F. and the relative humidity shall be 35 percent ± 5 percent at 70°F.

3.2 Pointing Control System

The test area for the checkout of the PCS will require an environment controlled to a class 10,000 Clean room (FS209a) with the temperature and humidity regulated to 70°F ± 5°F and a 35 percent RH respectively. The mounting of the solar sensors relative to target simulation will require isolation from geo-physical and cultural disturbances. See Figure 3-1.

3.3 Support Equipment

The ESE utilized in the testing of the PCS will require a cooling system to dissipate 15,000 watts of energy. The simulators utilized will be cooled by a water cooling system external to the test area but the simulators will require a Seismic pad for isolation from geo-physical and cultural disturbances.



SCALE 1/8 IN. = 1 FT 0 IN.

Fig. 3-1 Test Setup Showing Seismic Pad

3.4 Facilities

The MSFC Bldg. 4708 and the MSFC P&VE Laboratory are capable of supporting the testing of the PCS in its required test environment. The selection of a facility for the TV test will necessitate a further review.

4.0 TEST PROGRAM ELEMENTS

4.1 Acceptance Tests

4.1.1 Objectives

The objectives of the acceptance tests of the Pointing Control System (PCS) are to verify proper operation of the various PCS subsystems and compatibility with the corresponding electrical support equipment; to verify that the PCS subsystems conform to design specifications and interface properly with each other; and to verify proper operation of the PCS in an integrated systems test of the total ATM configuration.

4.1.2 Test Summary

The following tests will be performed on the PCS system in Post Manufacturing tests.

Alignment

Attitude Sensors

Digital Computer

Control Moment Gyro Systems

Experiment Pointing System

Integrated Tests

Redundant Tests

4.2 Alignment Tests

The objective of the verification will be to ensure optical and electrical harmonization of the PCS sensor inputs to LM indicator or CMG torque outputs. Verification will be made with the sensors energized and receiving radiation from a simulator.

4.2.1 Sensor Alignment

Experiment Pointing System Alignment Verification

Acquisition Sun Sensors Alignment Verification

Star Tracker Alignment Verification

4.3 Attitude Sensors Tests

4.3.1 Experiment Pointing System

Verify the functional operation of the EPS after installation into the ATM, then verify compatibility of the EPS with the PCS.

4.3.2 Acquisition Sun Sensors

Verify the functional operation of the ASS after installation into the ATM and then verify compatibility of the ASS with the PCS.

4.3.3 Star Tracker

Verify the functional operation of the ST after installation into the ATM, and then verify compatibility of the ST with the PCS.

4.4 Digital Computer

Verify, by interface tests, the compatibility between the Input-Output Assembly (I/OA) and the PCS system via their interfaces.

4.5 Control Moment Gyro Systems

Verify the CMG performance in an integrated system and evaluate the performance as interfaced with the ESE and the Pointing Control System.

4.6 Experiment Pointing System

4.6.1 Control Rate Gyro (CRG) Polarity Test

The output of each CRG (pitch yaw, and roll) must be verified for proper polarity with a rate input. The pitch and yaw CRG's may be verified by electrically or mechanically moving the ATM cruciform with respect to the frame at a proper rate. Care will have to be used in this test not to input excessive rates as the maximum range for the CRG's is only 1.0 degrees/second. If the above method is not practical, an alternate method of accomplishing this test will be to dismount the CRG's and install them on a test fixture for putting in a rate of the proper polarity. This second method is the way in which the roll CRG will have to be verified as it is mounted on the ATM rack. The output polarity of each CRG will be verified at both the CRG output and the Control Computer output.

4.6.2 CRG Torquing Test

Each CRG will be tested by putting inputs into the torquing circuit and then measuring the sensor output. The ESE which will provide this torquing function is not completely defined as yet. However, each CRG will be tested to as great an extent as is feasible within the ESE capability.

4.6.3 Control Computer ESE Verification Test

This test is run prior to the hookup of the PCS to its ESE. The purpose of this test is to verify that all monitor and control functions associated with the Control Computer ESE are operating properly before the start of the checkout. This test will include, but not be limited to, verification of switch functions. monitor functions, and input functions. The Control Computer ESE is not defined at this time, but the use of some type of Ground Electronic Test Set (GETS) may be necessary in performance of this test.

4.6.4 Control Computer/ESE Compatibility Test

This test is to be run just after hookup of the PCS. Part of the test will be run prior to application of power to the Control Computer to ensure all input power and control voltages are correct. The remainder of the test will be run after application of power and will verify that there are no problems in the interface between the ESE and Control Computer. This part of the test will include operation of all switch functions and input functions and verification of all monitor functions.

4.6.5 Control Computer Null Test

All Control Computer outputs going to the CMG's and the vernier control system will be checked to proper specifications. These nulls will be tested in various Control Computer modes both with inputs open and inputs closed. As part of this null test, the Control Computer output noise level will be measured and checked to tolerance.

4.6.6 Control Computer Mode Tests

All possible combinations of Control Computer modes will be energized and checks will be made to verify that the proper mode was selected. Various inputs will be induced and the proper signal paths will be verified for the mode selected. As part of this test, the interface between the Control Computer and Astronaut's Panel will be verified since mode selection will originate from this panel.

4.6.7 Control Computer/Digital Computer Interface Test

The interface between the Control Computer and the Digital Computer has not been defined completely as yet. There are a number of functions which will pass between these two systems which must be verified for proper operation. This test will verify all of these functions and check any to tolerance as necessary

4.6.8 Control Computer Gain Test

This test will be run to check all of the static gains of the Control Computer. Both attitude (psi) and Rate (psi dot) inputs will be induced and the Control Computer outputs monitored for proper level. These gains will be tested for all combinations of inputs. outputs, and modes.

4.6.9 Hand Controller/TV Display Compatibility Test

This test will verify proper operation of the hand controller with respect to the TV display system. Inputs will be injected for both positive and negative pitch and yaw to check for proper output and polarity on the TV display system. This system is not completely defined as yet but any adjustments or calibrations necessary for compatibility would be accomplished during this test.

4.6.10 Hand Controller Calibration

A calibration on the hand controller will be run to plus and minus full scale in both the pitch and yaw axis. As inputs are put in with the hand controller, outputs are monitored both at the CCEA and TV display. Data will be checked for null limits linearity, and hysteresis.

4.6.11 Vernier Control System Compatibility Test

This test will verify that the vernier control system is compatible with all systems it interfaces with such as Control Computer, LM display panel, Digital Computer. and ESE. Inputs will be put into the vernier system at the Control Computer and outputs will be checked at the various interfaces to assure compatibility.

4.6.12 Vernier Control System Static Calibration Test

A calibration shall be run in all axes (pitch, roll, and yaw) using a static input to the Control Computer and measuring position of the crusiform with respect to the ATM rack. Data from this test will be evaluated for null, limits, linearity, and hysteresis This test will be run with both an attitude (psi) input and a rate (psi dot) input.

4.6.13 Vernier Control System Dynamic Response Test

A dynamic response test will be run in all axes (pitch, yaw, and roll) using some type of dynamic input to the Control Computer and monitoring the vernier control system response. This test shall be run with dynamic inputs in both attitude (psi) and rate (psi dot).

4.7 Integrated Tests

4.7.1 General

A series of tests will be run on the entire PCS to verify complete end to end compatibility and check as much overall accuracy as is feasible. Included in this test will be introduced inputs from the various sensors in each axis and then measurement of the response at either the CMGs or the vernier system depending on the mode being tested. All modes of PCS operation and all possible sequencing will be verified in this test.

The PCS will be tested as much as is feasible during a Simulated Flight Test. This will include operation of all systems in as near to flight conditions as possible from prelaunch through the various orbital modes. Functions will be checked for proper operation and sequence.

4.7.2 Orbital Modes

4.7.2.1 Start, Stop, Standby Modes

Objective: This mode is used to allow the fine control subsystem to either start or stop the CMGs without imparting torque to the vehicle as the wheels are brought up to speed or shut down. This mode also allows performance of translation maneuvers (docking or station keeping). Vernier control and experiments should not be operated during spin-up. This mode should be selected in an emergency.

Description: Power is applied to the system by use of the switch selector through the ATM ADDRESS system. The START, STOP, TEST toggle switch in the MODW select portion of the PCS panel is momentarily placed in the START STOP position. Then the CMG power switches are activated through the switch selector by way of the ATM ADDRESS system. The condition of the CMGs is displayed for monitoring purposes on the CMG MOMENTUM dual meters and the dual MONITOR meter. The CMG MOMENTUM meters are constantly reading the position of the CMGs. The reading on the other position of the dual CMG MOMENTUM meter is controlled by the CMG MOMENTUM rotary selector switch. The MONITOR meter is controlled by the MONITOR selector rotary switch.

4.7.2.2 Experiment Pointing Mode

Objective: This mode is the primary operational mode and will be used during the majority of the daylight portion of the ATM mission once the initial acquisition has been accomplished. This mode places the fine control system in a solar oriented, stellar fixed condition and except for the override submode no manual control of the Cluster is possible. This mode is automatically switched to the Monitor and Acquisition mode during the dark portion of the orbit. The system remains in the M & A mode until otherwise commanded.

Description: The astronaut may point the experiment package to any feature on the sun's surface by moving either HAND CONTROLLER. Error signals are produced and displayed on the DIGITAL DISPLAYS. Each DIGITAL DISPLAY is controlled by the selector rotary switches located just to the left of the corresponding DIGITAL DISPLAY. These error signals are recorded on film for future reference. The gimbal angles of the star tracker (Rack orientation), vernier gimbal angles and other values may be displayed by proper selection of the keyboard. On either the H_T meter or any of the numerical readouts. It must be realized that proper scaling must be accomplished when the indicators are used for purposes other than their primary purpose. This is accomplished by reference to the display manual or charts located on the display.

In addition to pointing as a function of the numerical readouts, the astronaut may elect to point the ATM by observing the T.V. monitor displays located on the T.V. panel. This is accomplished by selecting the ATM Hα and WHITE LIGHT position on either CAMERA SELECT rotary switch. Verifying that the ATM Hα AND WHITE LIGHT CAMERA POWER toggle switch is also ON. The readouts on the DIGITAL DISPLAY will then indicate the orientation of the image. Calibration may be required (see each experiment). After a bias value has been obtained for any error in the pointing system, it must be recorded and used for resetting the PCS whenever each particular experiment is operated or for post flight evaluation of the data.

Once the location of an occurrance has been obtained by the PCS, the astronaut may begin the experiment. No further adjustment or the PCS should be necessary unless a new location is required or the particular set of experiments require a drift rate lower than the design tolerance. If it is desired to return to the vernier system solar center, the astronaut may switch the __________ toggle to the ____________ position or he may elect to use the HAND CONTROLLER. To return the roll gimbal to the zero position, the astronaut has the same choice. Switch the __________ toggle to the ______________ position or use the HAND CONTROLLER. The pitch and yaw gimbals automatically rezero themselves as the orbit approaches the sunset condition. The roll gimbal does not rezero automatically. The astronaut must rezero the roll gimbal.

4.7.2.3 Momentum Dump Mode

Objective: The purpose is to return momentum to a high level. This function is performed whenever the momentum indicators indicate a low value. It is desirable to complete momentum dump close to the point of sunrise to insure maximum undisturbed experiment time.

Description: The operational procedure used to accomplish momentum dumping requires two astronauts when in the Cluster configuration, one in the LM and one in the CSM. Verbal instruction from the LM to the CSM will be lused to direct the firing of the Reaction Control System (RCS). There are two methods for momentun dumping. The primary procedure is as follows.

The LM/ATM astronaut will read the momentum condition of each axis and from a table of values determine the required thrusters and RCS firing time for each set of thrusters. These firing times are given to the CSM astronaut who executes these instructions. Upon completion verification is made to the LM/ATM operator. The LM/ATM astronaut observes the TOTAL MOMENTUM indicator. It should return to near the optimum value when the Cluster is returned to the previous inertial position. Should an error be observed, this procedure should be repeated.

The secondary procedure is as follows. The LM/ATM astronaut requests that the CSM astronaut enter the INERTIAL HOLD mode by monmentarily placing the MODE switch to the I & M position. Upon verification (flag indicates I & M) the LM/ATM astronaut selects the MOMENTUM DUMP switch which forces the CMG gimbals to correct location. Upon the indication of MOMENTUM DUMP COMPLETE the ATM PCS resumes attitude control and the LM/ATM astronaut asks release from the CSM control. The MOMENTUM indicators should verify completion of momentum dumping by returning to a high value.

4.7.2.4 Acquisition and Monitor Mode

Objective: This mode is used to allow the Cluster to obtain pointing operation (pitch and yaw locked to solar center by coarse sun sensors) and roll position so that the principal axis of the S-IVB is aligned in the orbital plane about the earth.

Description: First the Reaction Control System (RCS) must be positioned so that the solar panels are pointed within a few degrees of the sun. This is achieved by positioning the ATM with the ATM hand controller. At this point the pilot in the CSM notifies the astronaut in the LM that they are ready for acquisition (this must be accomplished in the daylight period). The LM operator then selects the MONITOR & ACQUISITION mode by momentarily placing the proper MODE toggle switch in the

MONITOR & ACQ position. Verification that the PCS is in this mode is made by examining the MODE flag and verifying that M & A appears in the window of this flag. Activation of this mode automatically points the Rack within a few minutes of the solar center. Unless locked out specifically, (by entering the INERTIAL HOLD AND MANEUVER MODE command by momentarily placing the toggle switch in the I & M position) the pitch and yaw position reference will automatically enter an inertial hold mode just prior to entering the dark portion of the orbit, and solar reorient just after entering the daylight period. Once alignment is completed, either the Experiment Pointing mode, or the Inertial Hold mode may be entered.

4.7.2.5 Inertial Hold and Maneuver Mode

Objective: This mode is used when it is necessary, for any reason, to keep the ATM inertially fixed. It may also be used to provide a manual control of the Cluster attitude. This mode would be used where the switching transients are not desired or in the event of failure of the solar sensors.

Description: The only operations required during this mode are momentum dumping or reinitialization of the integrators due to drift of the equipment.

In the event that film retrieval or other extra-vehicular activity is required, the I & M mode would be used with the SUB MODE ROLL OVERRIDE to permit roll control of the experiment package from either the HAND CONTROL or an external control.

4.7.2.6 Test Mode

Requirements for the Test Mode of the PCS are as follows:

A. On the Input side the following:

a. Inputs into the Control Computer and

b. Substitutes for commands from the Control Computer have to be provided.

a) Inputs

Substitute for the Acquisition Sun Sensor:	Signal discrete
Substitute for the Fine Sun Sensor:	Signal discrete
Substitute for Pitch, Yaw and Roll rate:	Signal
Substitute for "Orbital Plane Update":	Signal discrete
Six commands from cockpit or simulation:	discrete

Binary coded 10 bit inputs from coding switches

Substitute for commands "Momentum dump"

b) Signals and Discrete from the Control Computer to peripheral input equipment.

Variable Pitch and Yaw bias for optical wedges

Torquing voltages for the Pitch, Yaw and Roll rate gyros

Discrete signal: "Star Tracker Mode"

Variable signals to simulate the manual operation

Simulate signals to represent H-Vector status of the CMGs.

4.8 Perturbed Control System Sequence

Objective -- Perform redundant tests at the highest level of integrated subsystem tests when the mode can be recognized as an individual function.

Operation -- Solar Occultation Sequence:

.1 FSS Sun Sensor loses its input reference signal (sunlight)

.2 FSS resets to Acquisition mode and Spar flex gimbal loops now operated in Rate Control mode via rate gyros

.3 ASS loses its input reference signals in its pitch and yaw axes

.4 ASS Sun Presence Detector switches its relay to Inertial Hold mode

.5 Precision pitch and yaw gyro control loops are switched from the ASS sunline and gyro caging feedback signal summing points to Inertial Hold mode

.5a Spar pitch and yaw servo control loop switched from FSS sunline reference and rate gyro signal summing points to Cage mode

.6 Precision pitch and yaw gyros now operating in Attitude mode

.6a Spar pitch and yaw flex gimbal servos slaved to their respective gimbal attitude pickoff signals

.7 Carrier pitch and yaw CMG control loops slaved to the precision pitch and yaw gyro gimbals respectively

.7a Spar pitch and yaw gimbals driven to their "null" attitude angle

Stellar Occultation Sequence

.1 Star tracker (ST) loses its input reference signal (star light)

.2 ST Star Presence Detector switches its relay to Inertial Hold mode

.3 Roll precision gyro control loop switched from Star Line and gyro caging feedback signal summing points to Inertial Hold mode

.4 Precision roll gyro now operating in Attitude mode

.5 ST gimbals now slaved to precision roll gyro gimbal

.6 Carrier roll CMG control loop slaved to precision roll gyro gimbal

4.9 Post Vibration Checkout

4.9.1 Pointing Control System Tests

Objective:

To reverify the PCS operation after each portion of Vibration Testing has been concluded. This will include reverifying each subsystem individually and collectively.

Description

After a phase of Vibration Testing is concluded, the first item of reverification which will be performed is alignment. During these tests, all or most of the same checks as made in Post Manufacturing Checkout will be re-run. Retaining proper alignment is possibly the most important single item in assuring PCS accuracies.

Each PCS subsystem, will be reverified by at least a functional test as a minimum. In some cases, it may be necessary to go into as much detail as is accomplished in Post Manufacturing Checkout. Regardless of the level of testing deemed necessary for each subsystem the Post Manufacturing Checkout (PMC) tests will serve as a basis for tests to be run. Data will be compared with the PMC test results to assure that no degradation has occurred as a result of Vibration Testing. Some type of PMC overall test will be run to assure system compatibility. Visual inspection will be made of each component to check for any structural damage to the component or mounting brackets as a result of vibration.

4.10 Thermal Vacuum Checkout

4.10.1 Pointing Control System Tests

Objective

To verify the PCS operation prior to the start of Thermal Vacuum Tests to ensure proper operation upon starting of tests in the Thermal Vacuum facility.

To monitor all PCS subsystems as much as it is feasible during the Thermal Vacuum testing to ensure proper operation.

Description

Prior to the start of Thermal Vacuum Testing, the Checkout station will have to be assembled at the Thermal Vacuum facility. The same ESE verification test as were run in PMC will again have to be run to assure proper configuration. After the ESE is verified, a checkout similar, or identical, to the one run on PMC will be run on the PCS. Data results will be compared with PMC test data to assure adequate correlation.

After a complete checkout has been accomplished, Thermal Vacuum Testing will begin. During the periods of testing under Thermal/Vacuum conditions all PCS will be monitored as much as feasible for proper operation. It is envisioned that the amount of PCS testing during this period will be quite limited due to the inaccessibility of the ATM. However, each system will at least be monitored for functional operation.

5.0 Abbreviations and Definitions

AAP	Apollo Applications Program
ASS	Acquisition Sun Sensor
ATM	Apollo Telescope Mount
ATP	Acceptance Test Procedure
CCEA	Control Computer Electronic Assembly
CMG	Control Moment Gyro
CMGCS	Control Moment Gyros Control System
CSM	Command and Service Module
ECE	Experiment Checkout Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Experiment Pointing System
ESE	Electrical Support Equipment
FSS	Fine Sun Sensor
GETS	Ground Electronic Test Set
GSE	Ground Support Equipment
GTP	General Test Plan
I/OA	Input-Output Assembly
KSC	Kennedy Space Center
LM	Lunar Module
LM/ATM	Modified LM Integrated with ATM
MSC	Manned Spacecraft Center
MDA	Multiple Docking Adpater
MSFC	Marshall Space Flight Center
PCS	Pointing Control System

PDP	Project Development Plan
PMC	Post-Manufacturing Checkout
RCS	Reaction Control System
RFI	Radio Frequency Interference
ST	Star Tracker